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NOTES ON THE LORRAINE FAUNAS OF NEW YORK AND THE PROVINCE OF QUEBEC

AUG. F. FOERSTE

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During the summer of 1912, through the courtesy of the Director, Dr. R. W. Brock, I was given the privilege of carrying on investigations on the Richmond and Lorraine formations of the province of Quebec, under the auspices of the Geological Survey of Canada. These investigations revealed the presence of a great thickness of red clays occupying the stratigraphical position of the Queenstown red clay shales in western New York. These red clay shales were underlaid by fossiliferous strata readily corre-

lated with the Richmond formations of Ohio, Indiana, and Kentucky, and below the latter was a great mass of strata, overlying the black shales which in this part of Canada are correlated with the Utica of New York. This intermediate great mass of strata, between the undoubted Richmond and the supposed Utica, was provisionally correlated with the Lorraine of New York, where, in fact, all of the strata below the Queenstown red clay shales, including the Richmond section, had been placed by the Canadian Geological Survey for a long time.

The known exposures of the so-called Lorraine Formations, in the province of Quebec, were isolated and rather widely scattered, and at first there appeared no prospect of determining their relative position with sufficient accuracy for stratigraphic purposes, but later a very long continuous section was found on the Nicolet River, southwest of Ste. Monique, which made it possible to make at least a beginning on such a line of investigation. At this locality, 157 feet of fossiliferous strata are regarded as undoubtedly Richmond, corresponding approximately to the middle and upper part of the Waynesville member of the Ohio section. The base of this known Richmond section is drawn at the lowest horizon at which *Strophomena planumbona* and *Rhynchotrema perlamellosa* have been found.

Below this lowest *Strophomena planumbona* horizon the section could be followed, along a continuous exposure up the river, for a total thickness, in descending order, of 2352 feet, or 2509 feet below the top of the fossiliferous section underlying the Queenstown red clay shales. This section by no means includes all of the strata down to the so-called Utica black shale, but it served to give clue to the approximate stratigraphic position of many of the isolated Lorraine exposures to be found within the province of Quebec.

It was noted, however, that there were no conspicuous stratigraphic breaks, and that a preliminary study of the fauna, in the field, did not reveal any sudden faunal changes, such as are very serviceable for stratigraphical purposes. It is evident that much detailed investigation is necessary before the full value of this wonderful section for stratigraphic purposes has been worked out.

Among other things, it was found difficult to determine, with confidence, the boundaries between the Richmond and the Lorraine. For instance, specimens belonging to the groups of

Whiteavesia pholadiformis and *Modiolopsis concentrica* occur for a distance of 200 feet below the lowest *Strophomena planumbona* zone on the Nicolet River. These species are common in the lower or Fort Ancient division of the Waynesville member of the Richmond in Ohio, but the similar forms in that part of the Nicolet river section here discussed are not accompanied by the other forms which in Ohio would be expected in the Fort Ancient division of the Waynesville. A similar difficulty was experienced in attempting to draw the boundary between undoubted Richmond strata and those to be assigned to the Lorraine in the section at Streetsville, and at other points farther west in Ontario; also in the numerous Lake Huron sections, for instance that southeast of Meaford, on Workman's Brook, and various sections near Little Current and Gore Bay, on Manitoulin Island.

The difficulty was increased by the fact that a very meager and poorly preserved fauna, submitted to Dr. E. O. Ulrich as coming from the same beds as *Whiteavesia pholadiformis*, in the Meaford and Little Current sections, on Lake Huron, suggested to him Middle Maysville (lower Bellevue) rather than Richmond affinities. Moreover, it is certain that the *Modiolopsis corrugata*, described by Miller and Faber from near the top of the hills back of Cincinnati, Ohio, is a genuine specimen of *Modiolopsis pholadiformis*, and there is every reason to suspect that the *Modiolopsis sulcata*, by the same authors and from the same general locality, belongs to the same species. If these forms were secured from some outlier of the lower or Fort Ancient division of the Maysville, at Cincinnati, this would be their normal position; but if they occurred at some lower horizon, then it might be that forms of the *Whiteavesia pholadiformis* group are not restricted to the Richmond, but occur also at lower horizons.

Under these circumstances it seemed desirable to become familiar with the New York Ordovician section, in order to learn if additional light might be secured from that source. The writer therefore took advantage of an invitation given by Dr. E. O. Ulrich to visit with him the territory east of Lake Ontario, in New York. The Lorraine exposures east of Pulaski, the Oswego sandstone section at the Salmon River Falls, and the fossiliferous sandstone section at the power house at Bennett bridge, a mile west of the Falls, and stratigraphically a short distance below the base of the Falls section were studied under his guidance. Sub-

sequently, various other sections were studied, and a fair reconnaissance of the Lorraine territory made.

One of the results of the investigations at the Bennett bridge locality was the discovery of very typical specimens of *Whiteavesia pholadiformis*, associated with *Ischyrodonta unionoides*, and other forms which Dr. E. O. Ulrich regarded as suggesting middle Maysville (lower Bellevue) affinities. Moreover, at the distinctly lower horizons exposed along the river east of Pulaski, the same *Ischyrodonta unionoides* occurred associated with various other forms which to Dr. Ulrich again suggested middle Maysville rather than Richmond affinities. This is not strange in view of the fact that this fauna at Pulaski contains *Trinucleus*. It is not intended by these observations to convey the impression that the middle Maysville age of the Pulaski and Bennett bridge faunas has been definitely determined, but rather that the Bennett bridge fauna, with its *Whiteavesia pholadiformis*, did not present other forms regarded as characteristic of the Richmond, while forms suggesting middle Maysville age were present there and at Pulaski.

For the present probably it would be safer to assume that the upper or Pulaski part of the Lorraine fauna is younger than the Eden at Cincinnati and older than the upper or McMillan division of the Maysville, while the lower, shaly part of the Lorraine, below the typical Pulaski zone, may be correlated with the Eden. In the absence of fossils, the typical Salmon river falls or Oswego sandstone may be correlated with the upper Maysville.

From the recent studies of Dr. Rudolf Ruedemann[1] it will be seen that the Utica black slate and the overlying dark Frankfort shales were described from the western or Trenton Falls basin of New York. In view of the presence of several basins already discovered it is necessary to remember that the territory west of Rome has not yet been investigated with the exactness demanded for exact correlation. For instance, while Vanuxem regarded the lower, more shaly part of the Lorraine section, in Oswego and Jefferson counties, as equivalent to the Frankfort shales of the Trenton Falls basin, it is by no means certain that the Frankfort shales extend this far west.

[1] The lower Siluric Shales of the Mohawk Valley, *Bulletin 162, New York State Museum*, 1912.

The Pulaski shales were described from the vicinity of Pulaski because here they occur unaccompanied by any other division of rocks. Ascending the stream toward Bennett bridge and the Salmon River Falls, the higher divisions of the Pulaski shales come in, very gradually however, owing to the general westward dip of the strata in this part of the state. Within the limits of the village of Lorraine, horizons are exposed which are regarded as belonging a short distance below those seen at Pulaski, but as still belonging to the Pulaski section. Strata equivalent to the horizons actually exposed at Pulaski come in east of Lorraine, and farther eastward the strata corresponding to the Bennett bridge horizons come in, chiefly however in the drift in the highest hills.

Owing to the westward dip of the strata, the thickness of the Gulf section northwest of Lorraine is less than indicated by vertical measurements above sea level. All of this Gulf section belongs below the level of the actual exposures within the limits of the village of Lorraine. According to Dr. E. O. Ulrich, who visited this section in the company of Dr. Ruedemann, the great mass of strata in the Gulf section shows Eden affinities, and therefore corresponds to the lower part of the Cincinnatian section. It is this part of the Lorraine which Vanuxem correlated with the Frankfort shales of the Trenton Falls basin, but at that time the fauna of the Frankfort shales had not been worked out and Vanuxem's correlation needs confirmation.

Both Dr. Ulrich and Dr. Ruedemann plan to make a more detailed study of the Lorraine in Oswego and Jefferson counties, and their researches will, no doubt, give the definiteness desired. In the meantime it may be observed that the Lorraine exposures of New York show much greater affinities with the much more extended Lorraine sections of the province of Quebec than with any part of the Cincinnatian section of Ohio and neighboring states. Moreover, on proceeding from Jefferson county, in New York, westward along the northern shores of Lake Ontario and northwestward toward Meaford and Manitoulin Island, the Lorraine facies of New York gives way to the Cincinnatian facies of southwestern Ohio, and neighboring states.

The exact significance of these observations is not understood as yet, but apparently the Frontenac axis was sufficiently developed in Lorraine times to prevent a ready access of Lorraine faunas to

the areas northwest of Lake Ontario, while permitting more ready migrations from the province of Quebec.

Nevertheless, there are evidences of the migration of Lorraine faunas even into Ontario. It is probable that the *Whiteavesia pholadiformis* fauna, just beneath the undoubted Richmond faunas, in the vicinity of Streetsville, and farther northwestward in Ontario, was connected with the Bennett bridge fauna, on the upper part of the Salmon River, in Oswego county, New York. Moreover, at the quarries on the Don River, in the eastern part of Toronto, *Trinucleus*, *Catazyga*, and *Leptaena* occur in an association suggesting the lower part of the Nicolet river section, in the province of Quebec, although *Leptaena*, so far, has not been found by me in the Lorraine of New York. *Leptaena tenuistriata* was listed by Walcott from the upper Lorraine fauna, estimated by him to have a vertical distribution of 500 feet beneath the Oswego sandstone, along the south branch of Sandy creek, Jefferson county, New York, but he lists also *Orthis biforata*, and therefore his specimens may, in part, have been erratic. The bryozoans of this Don river section were identified by Dr. R. S. Bassler with Eden and lower Maysville forms.

It is evident that the New York Lorraine section is a much abbreviated representative of the Nicolet river section. No doubt, considerable parts of the Nicolet river section will be found entirely missing in New York. The apparently entire absence of *Proetus* and *Leptaena* in the New York Lorraine, in view of the great vertical range of these fossils in the Nicolet river section, is significant in this direction. In view of these facts there is room for abundant future investigations.

The present paper began with a study of certain faunas, belonging to the Geological Survey of Canada, which had been collected in the vicinity of the Riviere des Hurons and Chambly village, east of Montreal, in the province of Quebec. The material under investigation was increased by collections made by the writer at numerous points in the province of Quebec, under the auspices of the Geological Survey of Canada. In the progress of these investigations it was found desirable to make a special study of the forms described by Hall from the Lorraine of New York. The following pages include a part of the results of these various studies. They differ greatly in value, according to the

familiarity of the writer with the material covered, but it is hoped that nevertheless they may have some value to those interested in these, or corresponding strata elsewhere.

1. **Lingula clochensis,** sp. nov.

(*Plate II, Figs. 11 A, B*)

Pedicel valve 20 mm. long; width 14 mm. along the anterior half of the valve, the sides being parallel here. Posteriorly, toward the beak, the shell narrows, becoming 12 mm. at 7 mm. from the beak, the postero-lateral parts being moderately convex, producing a rather obtuse beak. Anteriorly the lateral margins round rapidly into the moderately convex anterior outline. The anterior outline of the muscular scars reaches 10 mm. from the beak. Only the anterior part is clearly defined. This indicates the presence of a narrow low median septal ridge, less than 1 mm. in width at the anterior end. The total width across the muscular area anteriorly is 7.5 mm. Anteriorly this muscular area is crossed by transverse striae similar to those figured by Hall and Clarke, plate I, vol. viii, *Palaeontology of New York,* in the case of the species identified by them as *Lingula vanhornii* (= *L. modesta,* according to Schuchert), and in *Lingula densa.* Towards the sides these transverse striae are convex toward the front, but curve forward near the median septum. Convexity of the valve fully 2 mm. Notwithstanding this convexity, the median parts of the shell, from the beak to the anterior margin, are somewhat flattened from right to left, the area of flattening widening anteriorly, including nearly the entire width of the muscular area at midlength of the shell, and nearly the entire width of the valve at the anterior margin. Laterally, from the antero-lateral margins almost to the beak, the valve is flattened also, producing a moderately angulate outline in cross-section, the median flattened surface meeting two lateral flattened surfaces at angles of about 20 or 25 degrees. There are indications of concentric striae, and anterior to the muscular area the interior shows fine striae, radiating as though from the beak as a center. It is possible that similar radiating striae were present on the exterior of the shell.

Brachial valve, in the only specimen at hand, having a convexity of fully 2 mm., so that the total depth of the shell from valve to valve equals 4 mm., or one-fifth the length of the shell.

This valve is, of course, shorter than the pedicel valve at the beak, but the amount of shortening in the individual is abnormal, and, no doubt, not a constant feature of the species. The same median and lateral flattening is observed as in the case of the pedicel valve; anteriorly, the median flattened part is radiately striated, on the interior, as though from the beak as a center. The muscular markings are indistinctly preserved. Such outlines as are suggested by the specimen at hand are indicated in the accompanying drawing (Fig. 11 B), and since these do not conform to any structure known among *Lingulae* it is very probable that these outlines are misleading and have no diagnostic value.

Locality. Argillaceous brownish indurated bands, in the red clay shales in the lower Lowville section, on LaCloche peninsula, about a mile south of the contact of these shales with the quartzites mapped by the Canadian Geological Survey as Huronian. The fossiliferous layers occur a few feet above railroad level. The types were collected by A. F. Foerste in 1912 and form number 8403 and 8403a in the paleontological collections of the Geological Survey of Canada, in the Victoria Memorial Museum, at Ottawa.

Outline closely resembling *Lingula briseis,* Billings, but that species is a much flatter and narrower shell.

Lingula eva, Billings, is similar in the flattening of the median parts and also along the sides; but the sides are diverging rather than parallel anteriorly; nothing is known of the interior. *Lingula vanhorni,* Miller, is more attenuate posteriorly, more rounded anteriorly, and hence has a more ovate form.

2. **Lingula rectilateralis,** Emmons

Lingula rectilateralis was figured by Emmons in the *Geological Report of New York,* published in 1842, on p. 399. The only comment on this figure in the text is: "*Lingula rectilateralis,* is associated with *Triarthrus.*" On the same page: *Triarthrus beckii* is stated to be "abundant in gorges at Rodman and Lorraine, and upon the route from Adams to Tylerville, where the (Utica) slate is exposed." From these comments it is concluded that the specimen figured by Emmons came from the horizon of the black shale usually correlated with the Utica, and that it was obtained somewhere in the southern part of Jefferson county.

Regarding this species, Hall made the following observations, in the *Palaeontology of New York*, vol. I, p. 285:

> I am unable to perceive any essential differences between this shell and the *L. quadrata* of the Trenton limestone. The figure given by Professor Emmons has the sides straighter and the upper extremity more pointed than the original specimen. In two specimens examined (probably the originals of Fig. 1*a*, and 1*b* on plate 79) there is a slight difference in form, owing in part to compression; but there is no more deviation than is often observed in the same shell in the limestone. The surface is marked by concentric lamellose striae, and the center by nearly equal longitudinal striae; the sides are more or less straight, the base rounded with the upper extremity often subcuneate, having the slopes nearly direct. The base is sometimes nearly straight, and the shell resembles L. Lewisii.
>
> *Position and locality.* In the soft argillaceous shales in the lower part of the group at Loraine, Turin, and other places.

In the *Catalogue of the Types and Figured Specimens in the American Museum of Natural History*, the original of Fig. 1*a* on plate 79, is stated to have come from the Hudson River (not the Utica) at Lorraine, New York. The rock in which the specimen occurs, however, is sufficiently black to have come from the *Triarthrus becki* zone at the mouth of the Lorraine gorge. In Hall's specimen the anterior is rounded. Radiating lines fine and numerous, successively finer towards the sides of the shell. Apparently with a strong median septum and with cuneate concrete laterals, the anterior part of the middle pair corresponding to the centrals as in the group of shells including the one erroneously identified by Hall as *Lingula quadrata*, also *L. cincinnatiensis* and *L. iowensis*.

In his report on the Lower Siluric Shales of the Mohawk Valley, in *Bulletin 162 of the New York State Museum*, 1912, Ruedemann figures *Lingula rectilateralis* from the Schenectady beds, at the Dettbarn quarry, Schenectady, New York. In the accompanying text he states that Hall cited this species only from the middle and upper Trenton. From this it is evident that Ruedemann had in mind the Trenton species described by Hall as *Lingula quadrata*, and not the lower "Hudson River" form from Lorraine, Turin, and other places, to which Hall also applied the name *quadrata*. Hall refers to *Lingula rectilateralis* only in connection with the Lorraine form, since it was not the Trenton but the later (Utica) form, which had served as a type of the species for Emmons.

At the *Trinucleus* horizon, several hundred yards west of the

railroad bridge, about a mile east of Pulaski, a species of *Lingula* (plate III, Fig. 13) occurs which is distinct from *Lingula rectilateralis*. It is smaller and slightly less quadrangular. If lines are drawn from the beak to the antero-lateral angles, the concentric lines are much more conspicuous on the lateral parts of the shell than on the intermediate portions. The shell is very thin and there is no indication of longitudinal radiating striae along the middle parts of the shell, either on the exterior or interior surfaces. The shell apparently belongs to the group with a long median septum and with concrete laterals, such as are figured by Hall, in his monograph on *Palaeozoic Brachiopoda*, Plate I, Fig. 7, under the name *Lingula procteri*.

The following species were associated with the *Lingula* at the *Trinucleus* horizon, east of Pulaski: *Plectambonites, Dalmanella, Rafinesquina alternata* of very flat form, *Schizocrania filosa, Byssonychia radiata, Modiolopsis modiolaris, Colpomya pusilla, Cuneamya, Clidophorus planulatus, Archinacella pulaskiensis, Cornulites* of straight free form like *Tentaculites, Calymene*, and *Trinucleus*.

At the bridge south of Allandale, west of the mouth of the Lorraine gorge, the following species occur in the black shale commonly identified as Utica: *Glossograptus quadrimucronatus*, near mutation *postremus, Climacograptus typicalis, Mastigograptus* resembling *tenuiramosus, Schizocrania filosa, Leptobolus insignis, Zygospira* of *modesta* type, *Orthoceras, Triarthrus beckii*, and *Trinucleus*. This is the fauna usually identified as Utica in these more western areas, and it may be followed up stream into the mouth of the "Gulf." The graptolites were identified by Dr. Ruedemann.

3. **Pholidops subtruncata,** Hall

Pholidops subtruncata was figured by Hall from the exposures at Lorraine, New York. It occurs also east of Lorraine, where the road to Worthville crosses the creek, 2 miles west of the latter village; also northeast of Lorraine, along the creek within the limits of Barnes Corners. It is found also along the river about half a mile below Salmon Falls, a short distance below the level of the base of the Falls.

The name of the species is based upon the straightened anterior margin of the shell in the case of the type specimens. Speci-

mens having the same features occur along the Richelieu River, at Chambly; a very typical example, collected there by A. H. Foord, in 1881, is preserved in the Victoria Memorial Museum, at Ottawa, by the Geological Survey of Canada. It is not so certain, however, that this is a constant feature. The species is very abundant at many localities in the province of Quebec, and has a very considerable vertical range, but the subtruncate anterior margin appears to be an individual characteristic, rather than a prevailing one in the great majority of specimens to be referred to this species. *Pholidops,* apparently of the same type, occurs at various localities within two miles west and northwest of Vars, about 12 miles east of Ottawa, and also a mile west of Edwards station and a mile northwest of Hawthorne station. East of Montreal it occurs at Chambly, and St. Hilaire. Southwest of Three Rivers, it is found along the Nicolet River, southwest of Ste. Monique. Here it ranges from 75 to 1065 feet below the lowest horizon containing *Strophomena planumbona.*

4. **Glyptorthis insculpta,** Hall

The type of the genus *Hebertella* is *Hebertella sinuata,* Hall, from the Maysville division of the Cincinnatian. This type of shell is recognized in the Rogers Gap fauna, beneath the Fulton layer; in the Greendale division of the Cynthiana formation, where one of the species has been described as *Hebertella parksensis;* in the Trenton of central Kentucky, where one form has been described as *Hebertella frankfortensis;* in the Chazy of Canada, where *Hebertella borealis* occurs; and other species no doubt are found in still lower strata. The shell structure is fibrous and impunctate, and the surface is marked by fine concentric striae and lines of growth, but not by lamellose lines of growth. In mature shells, the median part of the brachial valve tends to become elevated anteriorly into a low broad fold which in some species is quite strongly developed.

In another group of shells, however, typified by *Hebertella insculpta,* Hall, the shell structure is not only fibrous and impunctate, but lamellate, and the surface of the shell is marked by lamellose lines of growth. Even in fractured specimens, the lamellose shell structure is readily detected. In the shells of this type, so far seen, there is no tendency toward a median fold in the brachial valve. *Hebertella insculpta* occurs in the Richmond; a

similar form, *Hebertella bellarugosa*, has long been known from the Trenton, Black River, and Stones River groups of the upper Mississippi valley, extending at least as low as the Ridley member of the Stones River, in central Kentucky and Tennessee. In New York, it occurs as low as the middle of the Chazy. From this it will be seen that both lines of descent can be traced back as far as the Chazy, and here they are already as strongly differentiated as at any later time. For the group typified by *Hebertella insculpta*, the name *Glyptorthis* is proposed. In both groups, there are forms in which the median part of the brachial valve is more or less strongly depressed, so as to produce a median sinus, so that the chief distinction of the *Hebertella insculpta* group is, after all, the presence of the concentric lamellose lines of growth, combined with a shell form which otherwise agrees with that of *Hebertella*.

Lamellose lines of growth occur also in species of *Eridorthis*, but in the latter group there is a tendency toward a fasciculate implantation of additional radiating plications, and the brachial valve, in its initial stages, begins with a median groove between two primary depressions, often distinct for a distance of 4 or 5 mm. from the beak, while the anterior half of the shell is marked by a low median fold involving the two median primary plications and 4, 5, or 6 additional implanted plications belonging to the same fascicles. The corresponding parts of the pedicel valve are marked anteriorly by a low median sinus, involving the median fascicle and the first major intercalated fascicle on each side.

In addition to *Hebertella insculpta* and *Hebertella bellarugosa*, the *Glyptorthis* group includes the species figured, but not described by Emmons, under the name *Orthis crispata*, in his report on the Geology of New York, published in 1842. It is possible that *Orthis nisis*, and *Orthis rugaeplicata*, both described by Hall and Whitfield from the Louisville limestone at Louisville, Kentucky, and figured in the *Twenty-seventh Report of the New York State Museum*, in 1875, belong to the same group.

5. **Glyptorthis crispata,** Emmons

(Plate III, Fig. 9.)

In the *Final Report on the Geology of New York*, Part II, published in 1842, Emmons figured a form as *Orthis crispata*, and states that it is associated with a form of *Dalmanella*, which he

figures on the same page as *Orthis testudinaria*, but that it is not so abundant as the *Dalmanella* at Lorraine. The associated form figured from Lorraine as *Pleurotomaria* is a *Hormotoma* of the *sublaxa* type. The *Tentaculites*, said to be more abundant near the upper part of the rock section at Lorraine, is the form with finer longitudinal striae described in this bulletin under *Cornulites*. In the work by Emmons the overlying Oswego gray sandstone is described separate from the Lorraine shales. Earlier in the same part of his discussion, Emmons notes the presence of *Trinucleus* "toward the upper part of the Lorraine shales, in a very fine bluish slate. The bed was exposed in repairing a mill dam near the center of Lorraine." Other species from the *Orthis crispata* horizon, northeast of the bridge in Lorraine, are: the so-called *Heterocrinus* and *Glyptocrinus* columnals, *Pholidops subtruncata*, *Plectambonites*, *Rafinesquina alternata* of very flat form, *Catazyga erratica*, *Cyrtolites ornatus*, *Archinacella pulaskiensis*, *Byssonychia radiata*, *Modiolopsis* belonging to the *concentrica* group, *Colpomya pusilla*, *Cuneamya* resembling the form here described as variety *brevior*, *Clidophorus planulatus*, *Ctenodonta lorrainensis*, *Lyrodesma poststriatum*, and *Calymene*.

Orthis crispata occurs also half way between Lorraine and Worthville, at the locality described elsewhere in these pages as 2 miles west of Worthville. Here it is associated with: the columnals usually referred to *Heterocrinus* and *Glyptocrinus*, *Pholidops subtruncata*, *Dalmanella*, *Catazyga erratica*, *Protowarthia*, *Cyrtolites ornatus*, *Hormotoma* belonging to the *sublaxa* variety, *Cornulites* having the appearance of *Tentaculites*, *Byssonychia radiata*, *Colpomya pusilla*, *Cuneamya*, apparently *Ischyrodonta unionoides*, *Clidophorus planulatus*, *Ctenodonta lorrainensis*, *Lyrodesma poststriatum*, *Calymene*, *and Trinucleus*.

The following is a description of *Orthis crispata*, drawn chiefly from specimens obtained 2 miles west of Worthville, on the road to Lorraine, since here the best preserved specimens were found.

Largest pedicel valve found, 17 mm. in length and at least 20 mm. in width, the lateral margins being not well preserved on one side. Largest brachial valve found, 12 mm. long and 16 mm. wide. The convexity of the pedicel valve was 4 mm., and that of the brachial valve 2 mm.

Pedicel valve more convex than the brachial valve, the greatest convexity being reached about a fourth of the length of the shell

from the beak. Cardinal area fully 2.5 mm. in height in the larger valves. Muscular area not obcordate, but narrowed anteriorly so as to give the deepest part of the area a rounded rhomboidal form with the greater axis extending parallel to the length of the shell. Adductor impressions occupying almost one-third of the width of the area, distinctly limited as far as the beak. Anterior to the middle of the adductor impression, there is a narrow thickening of the shell along the middle line, but this can be traced only a short distance. Laterally and antero-laterally from the muscular area there are long and rather distant radiating striae, usually called ovarian markings, but these rarely are preserved.

Brachial valve moderately and rather evenly convex. Cardinal process long, narrow, and thin. Crural plates strongly defined and terminating in sharp points. Anterior to the cardinal process the shell is thickened so as to produce a low broad elevation extending slightly farther than the anterior edge of the posterior adductor impressions. The posterior adductor impressions are only faintly delimited, and the anterior ones not at all, in the specimens seen so far.

Surface marked by rather angular plications, increasing by intercalation, about 5 or 6 in a width of 5 mm. along the anterior margin of the shell. Concentric striae lamellose, varying from 8 in a length of 4 mm. near the middle of the shell, occasionally to 12 in the same length near the anterior margin.

6. **Dalmanella centrilineata,** Hall

The types of this species were found, associated with *Trinucleus* and *Dalmanella*, at Lorraine. If our interpretation of this shell is correct, it is nothing but a small form of the ordinary *Dalmanella* so common at Lorraine, Pulaski, and elsewhere in the New York Lorraine. It is not mentioned by Hall and Clarke in their monograph on Palaeozoic Brachiopoda, in vol. viii of the *Paleontology of New York*.

7. **Strophomena planumbona,** variety

(Plate II, Figs. 4 A, B)

A species of *Strophomena*, (plate II, Fig. 4 A) belonging to the *planumbona* group, but subtriangular in outline, is labelled as

coming from Chambly on the Richelieu River and as collected by Foord in 1881. The same slab contains *Glossograptus* (*Orthograptus*) *quadrimucronatus-approximatus*, Hall and *Cymatonota recta*, Ulrich. The specimen is a pedicel valve 22 mm. long and 32 mm. wide, exposing the interior and, by exfoliation, also a cast of a part of the exterior. The lateral margins form angles of about 70 degrees with the hinge-line, produced to an angle of 50 degrees on one side by the lateral extension of the shell along the hinge-line. Width of muscular area 9 mm., length 7 mm., with a broadly rotund outline. The posterior diductor scars form a narrow strip only 1 mm. in width along the upper half of the lateral margin of the muscular area. The anterior diductor scars are much wider and do not show conspicuous flabellate markings. The adductor scars have a total width of 1.8 mm., being divided as usual along the median line by a prominent striation. Interior of shell only moderately thickened along the anterior border, the anterior half and the marginal parts laterally being crossed by radiate vascular markings which are only moderately conspicuous. The entire inner surface, aside from the muscular area, covered by a fine shagreen consisting of numerous minute granules visible under a lens. Exterior of pedicel valve evidently covered with finer radiating striae than those on the brachial valve, every fourth or sixth one tending to be slightly more conspicuous.

Two brachial valves, evidently belonging to the Chambly species occur among a group labelled as coming from the Riviere des Hurons, however, since the individual specimens are not labelled separately, there has been ample opportunity during the moving of collections, to mingle specimens from different localities, so that there is no absolute certainty that the two brachial valves in question came from the Riviere des Hurons. As far as their lithological appearance is concerned, they may have come from the Chambly locality. The brachial valve here figured (plate II, Fig. 4 B) is associated in the same slab with *Cleidophorus praevolutus*, and the other specimen is associated with *Rafinesquina mucronata*. It will be noted that in the *Report on the Geology of the Montreal Sheet*, by R. W. Ells, published in 1896 by the Geological Survey of Canada, Dr. Henry M. Ami lists *Strophomena* from the collections made at Chambly by W. E. Deeks in 1890, while no mention is made of the occurrence of *Strophomena* along the Riviere des Hurons. These brachial

valves show a convexity of about 7 or 8 mm., their greatest convexity being anteriorly, where the shell is deflected toward the anterior and antero-lateral margins. The radiating striae vary in size, three finer striae being intercalated between each pair of more conspicuous striae over the greater part of the valve, but along the anterior margin the intermediate striae become more conspicuous so that the difference in size is less noticeable. Here about 16 striae are seen in a width of 5 mm. Very fine concentric striae, seen only under a lens, are clearly indicated. Along the hinge-line there is a tendency toward wrinkling, the wrinkles being more perpendicular toward the beak and more oblique toward the postero-lateral angles. The wrinkling does not extend over the middle parts of the shell as in *Strophomena fluctuosa*. Interiorly, the central parts of the shell present a few vascular markings, rather inconspicuously developed, while laterally there are numerous radiating lines suggesting relationship to the so-called ovarian markings more conspicuously developed in other shells. The entire inner surface is covered with a fine shagreen, or by numerous minute granules seen only under a lens.

The occurrence of these specimens of *Strophomena* in the Lorraine areas east of Montreal is especially interesting in view of the entire absence of the *planumbona* group of *Strophomena* in the Maysville beds of the Cincinnatian province.

All of the specimens here described are preserved in the Victoria Memorial Museum, at Ottawa, by the Geological Survey of Canada. The original of Fig. 4A is numbered 8404, and that of Fig. 4B, 8405.

It is scarcely necessary to state that this occurrence of *Strophomena* of the *planumbona* type on the Richelieu River, at Chambly village is regarded as belonging more than 500 feet below the lowest horizon at which *Strophomena planumbona* occurs associated with *Rhynchotrema perlamellosa*, in the Richmond along the Nicolet River. A brachial valve of *Strophomena* was found also along the Nicolet River, at the highest *Leptaena rhomboidalis* horizon, in the lower part of the Proetus zone. Here it was associated with *Pterotheca pentagona*, a form described from Chambly. These occurrences of *Proetus*, *Leptaena*, *Strophomena*, and *Pterotheca* are noteworthy, since none of these genera are known in the Lorraine of New York.

8. **Rafinesquina nasuta,** Conrad

(Plate III, Fig. 2 A, B; Plate IV, Fig. 2 C)

Rafinesquina nasuta was described by Conrad, in the *Journal of the Academy of Natural Sciences of Philadelphia*, vol. VIII, part II, p. 260, in 1842, as follows:

> Triangular; longer than wide, slightly winged; inferior valve with the umbo and disk flattened; toward the base, suddenly and concentrically bent towards the upper valve; concentrically wrinkled; radii distinct, rather remote, with three or four minute intermediate lines; base projecting and angular in the middle.
>
> *Locality.* Near Rome, Oneida county, New York.
>
> This species resembles *S. alternata*, and *S. deltoidea* in having one or two of the central lines larger than the rest, but it is a much flatter and proportionately longer shell.

This horizon at Rome furnishes the types also of *Ischyrodonta curta*, *Lyrodesma plana*, *Pterinea demissa*, the forms of *Modiolopsis* for which Conrad proposed the term *angustifrons* but which Hall included in *M. modiolaris*, and *Orthodesma nasutum.* The horizon is about equivalent to that at Bennett bridge, one mile down stream from the Salmon river falls.

In the *Paleontology of New York*, vol. I, on plate 79, Hall represented similar forms, as found at Pulaski, suggesting the extremes of variation. Specimens of this type are common at one ferruginous horizon near the upper part of the *Trinucleus* zone, west of the railroad bridge, about a mile east of Pulaski. In one rock boulder found by Dr. E. O. Ulrich, a short distance west of the bridge, there were at least 100 valves of *Strophomena nasuta*, crowded together at all sorts of angles. In the majority of these the anterior nasute part was narrower than in Fig. 2*b* of Hall, although wider than in Fig. 2*a*, and the degree of inflection producing the nasute fold was intermediate to that shown by these figures. In the same rock boulder occurred *Dalmanella*, *Plectambonites*, *Cyrtolites ornatus*, *Byssonychia radiata*, *Modiolopsis modiolaris*, *Calymene and Trinucleus.*

A nasute form of *Rafinesquina* was found also in the stream bed at Barnes Corners, associated with *Pholidops*, *Plectambonites*, *Rafinesquina mucronata*, a flat form of *Rafinesquina alternata*, *Dalmanella*, *Archinacella pulaskiensis*, *Hormotona*, *Byssonychia radiata*, *Modiolopsis modiolaris*, *Colpomya pusilla*, *Cuneamya*,

Clidophorus planulatus, Orthoceras lamellosum, Cornulites of straight free type, resembling *Tentaculites, Calymene,* and *Trinucleus.*

Another nasute form of *Rafinesquina* was found at Worthville, associated with *Plectambonites, Dalmanella, Byssonychia radiata, Modiolopsis modiolaris, Orthodesma nasutum, Clidophorus planulatus, Ctenodonta lorrainensis, Lyrodesma poststriatum, Hormotoma, Cyrtolites ornatus, Cornulites* of straight free type, resembling *Tentaculites, Calymene,* and *Trinucleus.*

It is not likely that these nasute forms constitute a species distinct from *Rafinesquina alternata* as identified from the same beds, but their distribution at about the same horizon is possibly of significance for stratigraphic purposes.

Rafinesquina alternata was figured by Emmons from the Trenton of New York and the Trenton form is to be regarded as the type of the species. With this Trenton form it has been customary to identify all related forms in later rocks, up to the close of the Richmond. The discrimination of these forms into species and varieties is highly desirable.

9. **Rafinesquina squamula,** U. P. James

(*Cincinnati Quarterly Journal of Science, vol. 1, p. 335, 1874*)

Shell small, thin, semi-oval in outline, broader than long; hinge-line varying from a little more to a little less than the greatest breadth of the shell farther forward.

Dorsal valve slightly concave or nearly flat; cardinal line straight; cardinal area linear; a slight depression immediately forward of the beak. Surface covered, with fine, rounded radiating striae of nearly uniform size, increased toward the free margin by bifurcation.

Ventral valve slightly convex; beak and hinge-line slightly projecting; cardinal area narrow, a little the widest in the middle; foramen triangular and nearly closed by the cardinal process of the other valve; a strong mesial rib extending from the beak to the front; surface covered by fine, rounded, radiating striae, which bifurcate once or twice before reaching the free margins; the striae starting at and near the beak more prominent than the branching ones; crossed by very fine concentric lines, visible only

under a good magnifier, and even then in some cases quite obscure. Visceral space very little, the valves being so closely drawn together, translucent. Interior not observed.

Breadth of a full-sized specimen, $\frac{5}{8}$ inch; length, $\frac{1}{2}$ inch.

Position and locality. Cincinnati Group, about 350 feet above low watermark of the Ohio River, at Cincinnati.

Collected by U. P. James.

10. **Rafinesquina mucronata,** sp. nov.

(*Plate II, Figs. 7 A, B*)

Shell small, the length about three-fifths of the width, but varying in different individuals. Usually slightly extended along the hinge-line beyond the middle width of the shell so as to produce a small mucronate projection; but some individuals have rectangular posterolateral outlines. Usually obliquely wrinkled along the hinge-line. Radiating striae fine, with every fourth one distinctly more conspicuous along the middle and anterior parts of the valve; usually the stria found along the median line of the shell is more conspicuous than any of the remainder. Pedicel valve only moderately convex, the brachial valve slightly concave, almost flat.

Locality. Along the Nicolet River, southwest of Ste. Monique, from 80 to 870 feet below the lowest strata containing *Strophomena planumbona.* As type forms, those occurring between 80 and 530 feet below the lowest *Strophomena planumbona* horizon are selected. Here they occur associated with forms resembling *Whiteavesia pholadiformis, Modiolopsis concentrica,* and *Catazyga erratica.* In the underlying beds, *Proetus* becomes common. It occurs in the *Proetus* zone also at Chambly.

The specimens here figured were obtained west of Vars, at a locality found by going about a mile west from the station, along the railroad, and then a third of a mile northward along the road. Here it also is associated with *Catazyga.* It occurs also a mile farther north, at the first cross roads, and also along the railroad about a mile northwest of Hawthorne station.

The species appears closely allied to *Rafinesquina squamula,* James, from the Fairmount beds in the lower part of the Maysville division of the Cincinnatian strata in Ohio. The latter,

however, is not so characteristically mucronate at the ends of the hinge-line, nor so characteristically obliquely wrinkled along this posterior margin. Since the original description of *Rafinesquina squamula* is not readily accessible, it is here reprinted.

11. **Catazyga erratica,** Hall

Catazyga erratica, or rather *Orthonomaea erratica*, was described from drift material collected in Wayne or Monroe counties. It was reported by Hall from near Washingtonville, in Oswego county. Very typical specimens occur a short distance down stream from the railroad bridge, about a mile east of Pulaski. It occurs also at Lorraine village, a mile south of Barnes Corners, 2 miles northeast of Lorraine on the road to Worthville, and, at a higher level, about half a mile down stream from Salmon River Falls. If this species was found by Conrad it must have been included in the group identified by him as *Delthyris striatula*, under which name he listed chiefly the common *Dalmanellæ* of the New York Trenton and Lorraine. Washingtonville was located on Little Sandy creek. It was the type locality also for *Cyrtolites ornatus*. Hall listed from this locality also *Byssonychia radiata*, *Modiolopsis modiolaris*, *Clidophorus planulatus*, *Hormotoma gracilis*, *Ormoceras crebriseptum*, and *Rafinesquina alternata*, indicating that the exposures at Washingtonville correspond approximately to those east of Pulaski, near the railroad bridge.

Species of *Catazyga* occur at numerous localities in the province of Quebec in Canada. The various forms can be distinguished readily only when good specimens, preserving the original curvatures of the valves, are present. Flattened shells may be recognized readily generically, but the more exact specific determinations may be impossible. Usually, it is assumed that specimens occurring at the Richmond horizons belong to *Catazyga headi*, while those at lower horizons, in the Lorraine, all belong to *Catazyga erratica*. This, however, requires verification.

Catazyga occurs at various localities east of Ottawa. About a mile west of Edwards station, it occurs along a small stream southeast of a church located south of the pike. It formerly occurred along the railroad about a mile northwest of Hawthorne. Three-fourths of a mile west along the railroad, from Vars, and then half a mile northward, it occurs along the country road. A quar-

ter of a mile south of the railroad, along the same road, it is associated with *Strophomena fluctuosa*. All of these forms are regarded as *Catazyga headi*, although only at the last mentioned locality the associated fauna was regarded as Richmond.

Along the Nicolet River, southwest of Ste. Monique, *Catazyga* occurs at many horizons. The first specimens, in descending order, are met 97 feet below the top of the fossiliferous part of the Richmond, below the level of the red Queenstown shale division. It occurs also 7, 33, 44, 56, and 60 feet below this highest *Catazyga* level. At the top of this zone, 44 feet below the top, and at the base, *Catazyga* is associated with *Strophomena planumbona*. At the base, *Rhynchotrema perlamellosa* also is present, and the zone is included in the Richmond section, being regarded, together with the overlying fossiliferous part, as approximately equivalent to the Waynesville member of the Richmond. *Catazyga* is common also 4 feet below the lowest *Strophomena planumbona* zone, and, again, at 77 feet. At various levels, between 77 and 220 feet below the lowest *Strophomena planumbona* layer, *Whiteavesia pholadiformis* and a form resembling *Modiolopsis concentrica*, occur loose in strata which evidently were derived from this interval. Loose fragments of rock containing *Catazyga* occur at various intervals between 77 and 533 feet below the lowest *Strophomena planumbona* horizon, but in this interval *Catazyga* is very rare.

At the 533-foot level, *Catazyga* occurs associated with *Proetus*, this being the highest level for that trilobite, at this locality, but the *Catazyga* is not abundant until a level 580 feet below the lowest *Strophomena planumbona* is reached. At the 820-foot level, the first specimens of *Leptaena*, belonging to the *rhomboidalis* group, are seen, in descending order. Between the 580 and 820-foot levels, *Catazyga* occurs at numerous horizons, but is common only at the 650, 693, and 710-foot levels. *Proetus* occurs at numerous levels between the 533 and 820-foot zones. It is with this part of the Nicolet River section that the Chambly village exposures are correlated, while those exposures which contain *Whiteavesia pholadiformis* and the form resembling *Modiolopsis concentrica*, in the absence of *Proetus*, are correlated with that part of the Nicolet River section which lies between the 77 and 220-foot levels. The exposures along the road, half a mile south of the station at St. Hilaire, probably belong here.

Proetus ranges from the 533 to the 1002-foot levels, in descending order. At the 820-foot level, the *Pterotheca pentagona*, here described, was found. *Leptaena* occurs also at the 1284, 1338, 1515, 1699, and 1878-foot levels. Above the highest *Leptaena* horizon, at the 820-foot level, all of the forms of *Catazyga* resembled *Catazyga headi*. Between the 820 and the 1284-foot levels no specimens of *Catazyga* were noticed. At the 1284-foot level some poor specimens of *Catazyga* were found which could be identified only generically. *Catazyga erratica* was identified with certainty only at the 1390-foot level. The first specimens of *Trinucleus*, in descending order, are found at the 1552-foot level, and it has been followed below this level, at various intervals for fully 800 feet without reaching the base of its range in these strata. *Triarthrus* is known at present only from the 1653-foot level. The association of *Triarthrus*, *Trinucleus*, and *Leptaena*, seen on the Yamaska River, northwest of St. Hugues, is correlated provisionally with this 1653-foot horizon in the Nicolet River section. This, probably, is the horizon also of the exposures on the Becanceur River, about a mile and a half east of Breault station. The exposures southwest of Petite Caroline, containing *Leptaena*, and reported to contain *Trinucleus*, apparently belong somewhere between the 1550 and 1880 foot levels. The exposures at St. Hyacinthe are regarded as lower than anything studied so far along the Nicolet River, and those at St. Augustin and at the Montmorency Falls are regarded as far lower.

A considerable part of the fauna collected along the Riviere des Hurons, west of St. Jean Baptiste, has not been recognized as yet elsewhere. Owing to the presence of *Whiteavesia* of the *pholadiformis* group, and the absence of *Proetus*, however, these strata are correlated with the upper part of the Nicolet River section, somewhere between the 77 and 220-foot levels. It should be remembered, however, that *Whiteavesia* of the *pholadiformis* type occurs also at Chambly, and that the presence of a fossil is a safer guide to its stratigraphical position, than the absence of an expected form.

12. **Caritodens demissa,** Conrad

(*Plate I, Fig. 10; Plate III, Fig. 11*)

The specimen of *Pterinea demissa* here figured, from the Riviere des Hurons, presents the following characteristics. With increasing age the sinuosity of the anterior margin of the shell becomes more pronounced, the angle between the anterior margin of the ear and body increasing from less than 25 to frequently more than 55 degrees. This is due chiefly to a retardation of growth of the anterior margin of the body below its junction with the ear, and an acceleration of growth along the basal margin. A similar retardation of growth takes place along the line of junction of the posterior margin of the body with the wing. The result is that the anterior margin of the body becomes more erect, the shell is strongly prolonged in the direction of the basal margin, assuming a more oblong form, and the general appearance is that of a less oblique shell. In the meantime there is a considerable prolongation of the shell along the hinge-line, both anteriorly and posteriorly, these parts, usually, however, not being well preserved. In the fine-grained Lorraine sandstones, near Vars, east of Ottawa, the surface ornamentation is preserved in the form of fine, sharp, concentric striae, separated by much broader, flat, concentric spaces. Judging from well preserved specimens found in clays of the Richmond formation, on the Nicolet River, the sharp striae may have served as lines of support for narrow lamellose extensions of the shell, 0.5 mm. or less in width.

The shell substance evidently consists of two layers, of which the outer layer is very thin, rarely more than 0.25 mm., and often less in thickness; the inner layer frequently attains a thickness of 1 mm., and sometimes exceeds even 2 mm. in thickness. Specimens preserving both the outer and inner layers are common in the Richmond beds along the Nicolet River, several miles southeast of Ste. Monique, in the province of Quebec. In these specimens, the thick, inner layer appears to have undergone secondary crystallization; it is whitish in color, of loose texture, and probably dissolved readily under most conditions attending fossilization, since this layer so rarely is seen; its outer surface, where overlaid by the thin outer layer, is smooth, not showing the concentric striae belonging to the outer surface of the outer layer. The

outer layer is dark in color and dense in texture. This is the layer most frequently preserved, when any part of the shell is present. Shells in which the thick inner layer has disappeared usually do not present any trace of the inner surface of the valves so that the inner surface has long been unknown. Many strange things, however, may happen during the processes of fossilization. In the case of *Pterinea demissa*, when found in fine-grained sandstones, it occasionally happens that the rock, when split open, exposes on one piece the impression of the exterior of a valve, and on the other piece the impression apparently of the interior; but only the most pronounced features of the interior are retained, usually the crural ridges forming the jugum, to be described later, and the inner outline of the ligamental area. Superposed upon this cast of the inner surface of the valve are traces of the concentric, striate structure belonging to the outer surface of the valve, especially along the body of the valve.

The interior of the left valve, in one specimen from the Richmond strata along the Nicolet River, is characterized by a longitudinally striated ligamental area, 2.5 mm. in height near the beak. About 2 mm. below the lower edge of this ligamental area, a short distance posterior to the beak, the inner edge of the jugum is located. This is a lunate callosity or thickening of the interior of the shell a short distance below the ligamental area, the concave side facing the middle parts of the valve, the posterior extension curving away from the ligamental area, following approximately the line of junction between the body of the valve and the posterior wing, while the anterior crural ridge or anterior part of the jugum extends for only a short distance along the line of junction between the body of the valve and the anterior ear. This jugum is that part of the inner surface of the valve most commonly indicated in casts of the interior of the shell. Between the inner edge of the jugum and the lower margin of the ligamental area the shell is thickened. Transverse to this thickening, below the beak, there are several ridges serving as anterior cardinal teeth. In fact, the posterior extension of the jugum serves as a posterior lateral tooth. Nothing similar to this structure is known in the case of *Glyptodesma*. The nearest approach is seen in the shell described by Hall as *Pterinea flabella* from the Hamilton group of New York (*Paleontology of New York*, vol. V, part I, plate XIV, Fig. 19, and plate XV, Fig. 5). The posterior muscular scar is large and lies

a short distance below the termination of the posterior lateral tooth. The impression is very shallow and usually but faintly outlined. The pallial line also is faint. No trace of an anterior muscular scar has been noticed so far. The location for this scar should be just below the anterior termination of the jugum. It should be noted that the posterior crural ridge, forming the posterior half of the jugum of the right valve is exactly opposite the posterior crural ridge of the left valve, in this respect not fitting the ordinary conception of a tooth among the pelecypods.

The shell of the right valve frequently is as thick as that of the left valve, and it is similar structurally, but the valve is only slightly convex toward the beak, and becomes flattened, or even slightly oblique, toward the basal parts of the shell.

The specimen here figured, from the Riviere des Hurons, near St. Jean Baptiste, was collected October, 1872, by Thomas Curry. It is associated in the same slab with *Cymatonota recta*, Ulrich, *Byssonychia radiata*, Hall, *Cleidophorus praevolutus*, Foerste, and *Lophospira bowdeni-beatrice*, Foerste. It is numbered 8429, and is preserved by the Geological Survey of Canada in the Victoria Memorial Museum, at Ottawa. A younger specimen, No. 8433, from the same locality is represented by Fig. 11 on plate III.

The shell now known as *Pterinea demissa* was originally described by Conrad, *Journal of Academy of National Sciences, Philadelphia*, 1842, p. 242, plate 13, Fig. 3.) from the Lower Silurian sandstone near Rome, in Oneida county, New York. Here it was found associated with *Rafinesquina nasuta*, Conrad, in the quarries exposing the lower part of the grey sandstone overlying the Lorraine shales. The specimen figured by Conrad was a young individual, with a height from the ventral margin to the hinge-line of only 27 mm.

Along the Nicolet River, in the province of Quebec, *Pterinea demissa* is very common at several horizons in the Richmond. It occurs also at various horizons in the upper 500 feet of the underlying Lorraine section. It is found at Chambly, on the Richelieu river, and probably ranges throughout the *Proetus* division of the Lorraine in this part of Canada, although by no means as common in the Lorraine as in the Richmond. Small specimens occur half a mile south of the railroad station at St. Hilaire.

Specimens of *Pterinea demissa* occur at numerous localities within 12 miles east of Ottawa. Three-quarters of a mile west of

Vars, along the railroad, and then a third of a mile northward along a country road, it is found in the *Proetus* zone. Small specimens occur in the *Proetus* zone also a mile northwest of Hawthorne station, along the railroad. It occurs also over a mile west of Edwards station, along a creek southeast of a church on the Ottawa pike, associated with the following fossils: columnals usually referred to *Heterocrinus* and *Glyptocrinus*, *Pholidops subtruncata*, *Dalmanella*, *Hebertella*, *Plectambonites*, *Zygospira modesta*, *Byssonychia radiata*, *Cornulites*, and *Acidaspis*. Mr. W. R. Billings showed me a *Catazyga headi* said to have been obtained here.

Going from Vars about three-quarters of a mile westward, and then a quarter of a mile southward to a point where the road crosses a small stream, *Pterinea demissa* is found at a horizon provisionally regarded as Richmond, owing to the presence of the Richmond form of *Strophomena fluctuosa*. The remainder of the fauna consists of the following species: *Pholidops subtruncata*, *Crania*, *Lingula*, *Rafinesquina alternata* of flat form and fully 30 mm. in length, *Plectambonites*, *Catazyga headi*, *Zygospira modesta*, *Clidophorus* resembling *praevolutus*, *Byssonychia radiata*, *Modiolopsis* belonging to *concentrica* group, *Whiteavesia pholadiformis*, *Rhytimya*, *Lophospira* belonging to *bowdeni* group, *Cornulites* both attached and curved, and also straight and free, *Orthoceras*, *Bythocypris cylindrica*, *Calymene*, and *Isotelus*.

A third of a mile south of the *Strophomena fluctuosa* locality there is a cross road, near which, a short distance westward, a farm lane, formerly an open road, turns off southwards, and about half a mile down the lane reaches the highest fossiliferous strata of the Richmond, directly beneath the Queenstown shales. Residual blocks here contain *Pterinea demissa* associated with *Byssonychia radiata*, *Hebertella* resembling *occidentalis*, and numerous specimens of a *Zygospira* resembling *kentuckiensis*.

In the Cincinnatian areas of Ohio, Indiana, and Kentucky, *Pterinea demissa* also is much more common in the Richmond than in the Maysville. It appears absent in the Eden, but similar specimens occur in the Greendale and Rogers Gap divisions of the Cynthiana formation in Central Kentucky.

For *Pterinea demissa*, as identified from the lower Richmond strata of Ohio, the generic term *Caritodens* was proposed by the writer.[2] These Ohio specimens retained only the thin outer layer

[2] *Bulletin of Denison University*, vol. xvi, p. 71, 1910.

of the shell, and, therefore, did not exhibit the longitudinally striated ligamental area. It is evident now that the flexure of the outer layer of the shell, along the hinge-line, has no connection with the method of attachment of the valves to each other. The so-called single prominent linear posterior tooth in each valve is the posterior crural ridge or posterior half of the jugum.

13. **Byssonychia radiata,** Hall

(*Plate III, Figs. 12 A, B, C*)

Byssonychia radiata was described from the Lorraine of New York, and various specimens from the Cincinnatian of Ohio, Indiana, and Kentucky were identified with it. Among the Lorraine localities are mentioned: Boonville and Turin, in Lewis county; at Lorraine, Jefferson county; at Pulaski, Washingtonville and Mexico, Oswego county; near Rome, in Oneida county; but Fig. 4*a* on plate 80, accompanying the original description, in the *Paleontology of New York,* vol. I, represents a specimen obtained at Pulaski, and this is regarded as the type, while the specimen illustrated by Fig. 4*b*, obtained from an unknown locality in the same county, is regarded as the cotype.

Fig. 4*b* comes nearest to presenting the correct outline of the shell, especially those with the average number of plications. The upper part of the anterior margin is slightly concave owing to the forward curvature of the shell at the beak and the incurvature of the anterior face of the shell toward the byssal opening. The upper part of the umbonal ridge is never angular as in *Byssonychia richmondensis.* The angle between the anterior face and the cardinal margin usually varies between 85 and almost 90 degrees, but occasionally is as low as 80 degrees. The length of the cardinal margin usually is about half the greatest length of the shell, from the beak toward the posterior part of the nearly evenly convex basal margin. Occasionally, the cardinal margin equals about three-fifths of the greatest length of the shell. The ratio of the greatest width to the greatest length, measured diagonally across the shell from the beak to the posterior part of the basal margin, usually is about 77 per cent, but may vary from as low as 70 to as high as 81 per cent. The convexity of the single valve usually does not exceed 6 mm. in a shell having a maximum length of 36 mm. Shells exceeding 40 mm. in length are rare.

The number of radiating plications appears to vary considerably. If only those shells are selected in which both the cardinal margin and the anterior face are well exposed, then 45, 46, or 47 radiating plications are very frequent. However, specimens occur in which the number of plications is as great as 55. In the specimens with 45 radiating plications, these plications are distinctly broader than the intervening grooves; in those with 55 plications, the width of the latter exceeds that of the intervening grooves only slightly, if at all. Since the number of plications is considered as of diagnostic value in the genus *Byssonychia*, an attempt was made to discriminate two species among these Lorraine forms from Pulaski, but without success. Some of the forms with the greater number of plications are slightly more erect and somewhat longer along the hinge-line, but others have the larger number of plications without differing in form or outline from those specimens in which the number of plications is smaller, and, of course, specimens with intermediate numbers occur. At Pulaski, specimens with about 45 plications are rather abundant both in the gorge south and southwest of the town, and also along the river banks eastward, as far as the railroad bridge. Specimens with 55 plications occur, associated with the others, at the *Trinucleus* horizon, several hundred yards west of the railroad bridge. In none of the specimens does the posterior margin meet the cardinal line as in the illustration of *Byssonychia praecursa*, Ulrich, on plate 45 of the *Geology of Ohio*, vol. VII. The angle is much more obtuse, the posterior margin, in most specimens, rounding almost gradually into the cardinal outline.

The statement by Hall that *Byssonychia radiata* has 25 to 40 plications probably indicates that he had specimens with 45 plications in his possession, those on the anterior face not being well exposed. The specimen illustrated by Fig. 4*a*, on plate 80, of the *Paleontology of New York*, vol. I, was examined for me very obligingly by Dr. Chester A. Reeds, and found to possess 48 radiating plications. The original of Fig. 4*b* exposes 42 plications and about 6 are still covered by rock. In 4*f*, 50 plications are certain. In 4*c*, 28 plications are visible but additional ones are present but not exposed. See Fig. 12*c*, pl. III, this BULLETIN.

The vertical range of *Byssonychia radiata* is considerable. It occurs at Bennett bridge, and also half a mile eastward up the river, and the same distance west of the Salmon River Falls.

It occurs also at lower horizons than those exposed at Pulaski; for instance in the Lorraine Gulf, where it was cited by Emmons from within 4 feet of the upper part of the Triarthrus zone.

Along the Nicolet River, in the province of Quebec, *Byssonychia radiata* ranges through the *Proetus* zone and downward into the upper part of the *Trinucleus* zone. Upward, it appears to range as far as the upper parts of the fossiliferous Richmond, just beneath the Queenstown shale, but this requires confirmation since the Nicolet River section was studied before numerous typical specimens from the Lorraine of New York were at hand.

14. **Colpomya faba-pusilla,** var. nov.

(*Plate II, Fig. 10; Plate III, Fig. 4 A, B*)

Greatest length of largest specimens known about 10 mm., cardinal margin straight for a distance of about 5 mm. posterior to the beak, rounding into the oblique posterior margin of the shell. There is considerable variation in the obliquity of this posterior margin; in the shells having a more vertical posterior margin, the length of the straight hinge-line posterior to the beak may equal nearly 6 mm., while in the shells having a strongly oblique posterior margin the straight hinge-line may extend but slightly more than 4 mm. beyond the beak. Mesial sulcus strongly defined from the beak to the basal margin, its deepest part forming an angle of about 70 degrees, varying in some shells to 60 degrees, with the cardinal outline. Anterior to the mesial sulcus the shell is only moderately convex. Posterior to this sulcus, however, along the umbonal ridge, the shell is strongly convex, this convexity becoming almost angular toward the beak. The angle between the umbonal ridge and the cardinal margin varies usually between 40 and 45 degrees. Anterior margin more narrowly rounded, extending about 2 mm. anterior to the beak.

Maximum length, measured diagonally, 10 mm.; height posteriorly, between 5.5 and 6 mm.; height at the beak, about 4.5 mm., but varying from a little less to a little more than this height; convexity of the single valve, about 1.75 mm. in shells showing the strongest convexity.

Surface with very fine concentric striae, visible under a lens. Interior with a small muscular scar near the upper anterior margin;

hinge unknown, and hence the generic reference is based merely upon the general appearance of the exterior of the shell.

Locality. At the *Trinucleus* horizon, several hundred yards west of the railroad bridge, east of Pulaski, New York. The same form is found also at the eastern edge of Lorraine village and at the road crossing over the creek, two miles west of Worthville, in the same state.

The original of Fig. 10 on plate II, since lost in the Dayton flood, was collected by Aug. F. Foerste, in 1912, on the Richelieu River, at Chambly, associated in the same rock fragment with *Catazyga headi* and *Proetus*. An impression of the same species from the same locality, numbered 8430, is preserved in the Victoria Memorial Museum at Ottawa, Canada.

Modiolopsis faba, (Conrad) was figured by Emmons[3] from the black irregular-bedded limestone at Watertown, New York, where it was said to be abundant. His figure most closely resembles Fig. 6*a* on plate 35, in vol. I, of the *Paleontology of New York*. In this volume the horizon is described as belonging to the concretionary layers of the Trenton limestone, at Watertown. This would place it in the basal Trenton. Compared with typical *Colpomya faba*, the valves of *Colpomya pusilla* are relatively higher posteriorly and lower at the beak, owing to the stronger divergence of the basal margin from the cardinal outline, amounting frequently from 30 to 35 degrees. The beak projects more distinctly above the cardinal margin, and the cardinal part of the anterior margin rises more nearly to the level of the straight cardinal outline of the shell posterior to the beak. The mesial sinus begins at the beak as a depression near the middle of the umbones; it tends to be more oblique than in *Colpomya faba*, but, as a matter of fact, the Lorraine form is scarcely distinguishable from the Trenton types.

The Lorraine form was figured by Hall from casts in the sandstone layers forming part of the section at Pulaski, New York. The specimen represented by Fig. 4*a* on plate 82 of vol. I, of the *Paleontology of New York*, forms No. 736–4, in the American Museum of Natural History. Fig. 4*b*, on the same plate, unquestionably represents the same species, although the original of this figure has been lost.

[3] *Geological Report*, New York, 1842, p. Fig. 5.

15. **Pholadomorpha pholadiformis,** Hall.

(*Plate II, Fig. 16; Plate V, Fig. 4*)

Cardinal and basal margins diverging at an angle of about 20 degrees. Basal margin almost straight; at a point almost vertically beneath the beak it rises gradually toward the strongly rounded anterior margin. The latter extends 12 mm. anterior to the beak. Posteriorly the cardinal margin is fairly straight for about 35 or 40 mm. and then rounds gradually into the very oblique posterior margin, forming an angle of about 130 or 135 degrees with the latter. The margin is strongly rounded at the posterior extremity of the umbonal ridge. The umbonal ridge is low and very broad; it is moderately distinct for a distance of nearly 30 mm. from the beak, but merges into the general convexity of the shell posteriorly. From this umbonal ridge the slope toward the basal margin and toward the cardinal margin is rather flat. There is no mesial sinus anterior to the umbonal ridge. The shell is concentrically striated. These striae are most distinct along the anterior half, below the umbonal ridge, and along the posterior half, above this ridge, where the low transverse plications are less distinct or absent. The transverse plications cover the slope beneath the umbonal ridge almost as far to the front as the area beneath the beak, although anteriorly these plications no longer reach the basal margin of the shell. They are approximately vertical to the basal margin, although curving moderately forward on approaching the umbonal ridge. Similar low transverse plications may be detected along the cardinal margin from within 20 mm. of the beak to about 10 mm. beyond the point where the cardinal margin curves downward into the posterior margin of the shell. These plications form angles of about 70 degrees with the cardinal margin, and the longest, posteriorly, scarcely extend more than 5 mm. from the cardinal outline. Along the basal margin, these plications number about 3 in a length of 5 mm.

Locality. At the power house, about a mile southwest of the of Salmon River Falls, New York; in the upper areanaceous part the fossiliferous Lorraine.

Essentially the same form occurs in the Lorraine at Gorrel Point, two miles northeast of the village of Gore Bay, on Manitoulin Island, in Lake Huron. Fig. 16, on plate II, represents

one of these specimens, collected in 1911, by Aug. F. Foerste. The angle between the cardinal and basal margins is nearer 15 degrees, and the number of transverse plications along the lower half of the shell is nearer 4 or 5 in a length of 5 mm. These differences lie easily within the range of variation of this species. The specimen is numbered 8416 and is preserved in the Victoria Memorial Museum at Ottawa, Canada.

Whiteavesia pholadiformis was described by Hall from the Little Bay des Noquets, on the western side of Lake Michigan, in the *Report on the Geology of the Lake Superior Land District,* 1851, p. 213, and several figures were presented.

Among four specimens from the type locality, and belonging to the type series, No. 1365, but not figured by Hall, it is possible to distinguish two forms. Two of the specimens are quite elongate; one of these preserves the posterior outline but the part anterior to the beak is lacking; the other presents the anterior outline but not the posterior outline of the shell. The shell was of moderate height anteriorly, and the beak is rather distant from the anterior margin. The general outlines of these shells probably closely resembled that of Fig. 16 on plate II of the present publication. The other two specimens from the type locality evidently were higher and more broadly rounded anteriorly, and, judging from one of them, a so-called exterior-interior impression, also shorter. The transverse plications below the umbonal ridge are well developed in both forms, but the post-umbonal plications are only moderately developed, as in Fig. 16 on plate II, and not as in the form here called *divaricata.* The more elongate forms, resembling our Fig. 16, are regarded as the typical forms of *pholadiformis.* Figure 4 on plate V is one of Hall's types.

Forms unquestionably belonging to the *Whiteavesia pholadiformis* group, and usually identified with that species, occur also in the Lorraine of the province of Quebec. They occur associated with *Strophomena fluctuosa* about a mile west of Vars, a short distance south of the railroad. They also occur in the upper part of the Lorraine along the road, south of the railroad station at St. Hilaire. Along the Nicolet River, southwest of Ste. Monique, it occurs in the Richmond strata, 97, 110, and 120 feet above the lowest horizon containing *Strophomena planumbona.* It is found here also loose at 136, 220, and 430 feet below this *Strophomena planumbona* horizon, evidently in strata belonging to the upper

part of the Lorraine section, as here interpreted. It will be necessary to collect the specimens in order to assign them to their proper species, now that the presence of several species of this type is suspected.

It is scarcely necessary to state that the group of species typified by *Modiolopsis pholadiformis* does not belong to the genus *Whiteavesia*, as typified by *Whiteavesia cincinnatiensis*, Hall and Whitfield The striations of the latter are narrow and more or less radial, while the plications of the *Modiolopsis pholadiformis* group, along the basal margin, are broad and more or less transverse to the longitudinal axis of the shell, and posteriorly are more or less divergent from the umbonal ridge. For the latter the designation *Pholadomorpha* is here proposed, with *Modiolopsis pholadiformis* as the type.

16. **Pholadomorpha pholadiformis—divaricata**

(*Plate II, Fig. 14*)

Basal margin forming an angle of about 18 degrees with the cardinal margin; this results in a remarkably narrow outline anteriorly, which may be due in part to compression. Posterior margin very oblique, rounding gradually into the cardinal margin, and much more rapidly into the basal outline. Shell concentrically striated, but the conspicuous ornamentation consists of the low, broad, transverse plications characteristic of the species. These plications cover the lower slope of the shell, from the basal margin to the crest of the umbonal ridge, from the lower posterior angle to the anterior muscular area. The shell as a whole appears to have been shorter, and more convex; posteriorly the plications are much more oblique to the basal margin, especially toward the umbonal ridge which they approach here with a strong forward curve; toward the middle of the shell this forward curvature becomes less pronounced, and near the beaks the plications are almost vertical. Along the cardinal margin the low transverse plications are nearly vertical for a distance of about 2 mm., posteriorly, and then curve rapidly forward on approaching the umbonal ridge. Even along the upper part of the posterior margin, these low transverse plications curve first obliquely downward and then much more strongly forward on approaching the

cardinal ridge. Even the lower part of the posterior termination of the shell, above the umbonal ridge, is occupied by oblique plications. Transverse plications vary in number from 10 in a length of 10 mm. near the anterior part of the shell to 6 in the same length posteriorly. Length 66 mm., height posteriorly 31 mm., height at beak 20 mm., possibly shortened here by compression. Anterior margin extending 10 mm. anterior to the beak, convexity of the single valve about 7 mm.

Locality. Riviere des Hurons, near St. Jean Baptiste; collected October 1872 by Thomas Curry; forming specimen No. 2071, Paleontological Collections, Geological Survey of Canada, Victoria Memorial Museum, Ottawa, Canada.

The chief characteristics of the form here described are its shorter length, its greater convexity, and the more pronounced forward curvature of the low transverse plications. If these characteristics do not prove fairly constant, when numerous specimens from the same locality are collected, this form has no standing whatever, even as a variety.

The chief reason for describing the preceding specimen is the fact that this gives an appropriate opportunity to discuss the form described by Hall and Whitfield as *Sedgwickia? divaricata.* Although the type of this species should occur in the U. P. James collection, at Chicago University, it is unknown there. It was found in the shales of the Richmond group at Blanchester, Ohio. A mile northwest of Blanchester, where the north and south road crosses Second Creek, the lowest exposures belong to the lower *Hebertella insculpta* horizon, at the base of the Blanchester division of the Waynesville, but there is good collecting from here westward down the stream. Knowing this area very well, I am of the opinion that if ever the type of *Sedgwickia divaricata* is found it will prove to be a young specimen belonging to the *Whiteavesia pholadiformis* group. In young specimens of this species the basal margin is convex, and the umbonal ridge is fairly angular. Moreover, the concentric markings sometimes are fairly conspicuous on the cardinal slopes, and would be especially conspicuous on specimens in which these concentric markings were conspicuous below the umbonal ridge. Judging from the figure of *Sedgwickia divaricata* published in vol. ii of the *Palaeontology of Ohio,* the type specimen presented the low broad plications curving from the posterior margin of the shell obliquely forward

toward the umbonal ridge, as well as the concentric markings which sometimes are strongly developed here I regard the drawing of this form in the *Ohio Palaeontology* as misinterpreted and would not be surprised to learn that the details had been too strongly accentuated.

17. **Pholadomorpha chambliensis,** sp. nov.

(*Plate I, Fig. 8*)

Shell transversely oblong, the cardinal and basal margins diverging scarcely 10 degrees. The anterior margin is more broadly rounded and the posterior margin is less oblique than in typical Modiolopsis pholadiformis. The low transverse plications can be detected only on the posterior half of the shell, on the slope beneath the umbonal ridge, but they may be more distinctly indicated in other individuals. Umbonal ridge angulate along its upper outline for a distance of about 15 mm. from the beak, rounding rapidly posteriorly, merging into the general convexity of the shell.

Length 68 mm., height posteriorly 28 mm., height at beak 24 mm., extension of shell anterior to beak about 12 mm., convexity of the single valve about 3 mm.

Locality. Apparently from Chambly, from a siliceous limestone containing Byssonychia radiata, Rafinesquina alternata, and apparently also Catazyga headi. Specimen No. 2069, Geological Survey of Canada, in the Victoria Memorial Museum, Ottawa, Canada.

18. **Modiolopsis modiolaris,** Conrad

(*Plate III, Fig. 1; Plate V, Figs. 1 A, B, C, 2 A, B, C*)

In the *Second Annual Report of the New York Geological Survey,* 1838, Conrad described this species as follows:

> Shell ovate oblong, compressed; surface with coarse concentric lines, obsolete on the posterior side; posterior extremity obliquely truncated. Length, nearly 3 inches. *Locality,* Pulaski, Oswego county, with the preceding (*Cymatonota pholadis*).

The writer has recently collected *Modiolopsis modiolaris* in the same slab with Cymatonota pholadis, a short distance down

stream from the railroad bridge, about a mile east of Pulaski, and this is regarded as the type locality for both species.

In the *Paleontology of New York*, vol. I, 1847, on plate 81, Hall presents various figures of *Modiolopsis modiolaris*. Of these, Figs. 1*a*, *b*, represent specimens collected at Rome, while 1*c*, *d*, and *e* were drawn from specimens secured at the type locality, at Pulaski. Regarding Fig. 1*a*, Hall states: "This is one of the most perfect forms, and the one to which Mr. Conrad applied the name *modiolaris*." In one respect his published figure, however, differs from the specimens collected at the type locality: the angle between the cardinal and basal margins is greater. This is shown by the following table, giving the measurements for three specimens collected at Pulaski, one from half a mile east of Worthville (plate III, Fig. I), and for Fig. 1*a*, left valve, as published by Hall on plate 81 of the publication cited. (See Figs. 1, 2, on Plate V.) Measurements are given in millimeters.

LOCALITY	GREATEST LENGTH	POSTERIOR HEIGHT	HEIGHT AT BEAK	ANTERIOR MARGIN FROM BEAK	CONVEXITY OF SINGLE VALVE	ANGLE BETWEEN CARDINAL AND BASAL MARGINS	BETWEEN CARDINAL AND POSTERIOR MARGINS
Pulaski.....	57.0	26.0	20.0	10.5	4	11°	44°
Pulaski.....	59.0	27.0	20.0	10.0	4	11°	38°
Pulaski.....	63.5	30.5	25.0	12.0	4	10°	42°
Worthville....	70.0	32.0	23.5	10.0	4	12°	39°
Fig. 1*a*, Pl. 81.	69.0	33.0	22.0	11.0		19°	42°

Shell obliquely oblong. The cardinal margin posterior to the beak nearly straight, rounding gradually into the oblique posterior margin. Anterior to the beak, the cardinal margin is deflected downward, and then rounds into the strongly curved anterior margin of the shell. Basal margin straight along that part of the shell which lies directly opposite the straight cardinal margin; rising gradually toward the curved anterior margin, and more rapidly toward the posterior margin, which is most curved at the posterior extremity of the umbonal ridge. Umbonal ridge most strongly defined on the cardinal side and within about 10 or 15 mm. from the beak, almost disappearing into the general convexity of the shell posteriorly. Mesial sinus practically obsolete, although occasional specimens show a very faint indication of the same accompanied by a scarcely perceptible concavity of the

basal outline. General convexity of the shell small. Concentric striations best defined anteriorly, along that part of the shell which is anterior to the oblique umbonal ridge. Anterior adductor depressions large and distinctly defined, although usually very shallow, owing to the thinness of the shell. The interior of one of the valves is faintly striated posteriorly, below the umbonal ridge, in a direction parallel to a line drawn from the posterior termination of the umbonal ridge to a point half way between the beak and the upper anterior margin of the shell.

Locality. Pulaski, a short distance down stream from the railroad bridge, about a mile east of the town; also in the Trinucleus horizon, a short distance farther down stream; and still farther down stream, below the dam, at the southwestern margin of the town. Within the village of Barnes Corners; also a mile southward. At Worthville, and also half a mile eastward. At the school at the head of the road from Turin westward through the Gulf and then southwestward up the hill. Half a mile down stream from the Salmon River Falls, a short distance below the level of the base of the falls.

19. **Modiolopsis concentrica,** Hall and Whitfield

Modiolopsis concentrica was described from the Waynesville beds near Waynesville, Ohio.

In Canada, specimens occur which unquestionably belong to the same group and are closely related, but the latter may not prove identical. One of these specimens, collected at Chambly, presents the following characteristics. The curvature of the shell along the hinge-line passes gradually into that of the strongly deflected posterior outline, as in *Modiolopsis concentrica,* but the concentric plications along the post-umbonal parts of the shell are far less conspicuous, the umbonal ridge is flatter, the area which should be occupied by a mesial sinus is scarcely concave, and the basal margin of the shell is scarcely concave.

Locality. Specimen numbered 1545 and labelled as coming from Chambly. Preserved in the Victoria Memorial Museum, at Ottawa, by the Geological Survey of Canada.

Modiolopsis concentrica does not belong to the group of *Modiolopsis modiolaris.* An examination of the types, in the Museum at Albany, New York, indicates that *Modiolopsis modiolaris*

belongs to the group of shells having a comparatively straight hinge-line posterior to the beak, and a moderately convex or nearly straight, instead of concave basal margin; there is no mesial sulcus; and the anterior margin of the shell extends conspicuously in front of the beaks.

20. **Modiolopsis postplicata,** sp. nov.

(*Plate I, Fig. 4*)

Hinge-line arcuate posterior to the beak, gently declining toward the posterior extremity and gradually rounding into the oblique posterior margin; umbonal ridge broad and low, rounded rather than angulate; mesial sulcus shallow, forming an undefined depression across the valves from the beak toward a point slightly anterior to the middle of the basal margin, where the latter is slightly concave; cardinal or post-umbonal slope marked by regular, even, concentric plications becoming obsolete toward the crest of the umbonal ridge; these plications mark successive growth stages of the posterior margin of the shell; there are about 5 plications in a length of 5 mm., increasing to 6 in the same length posteriorly; within 10 mm. from the posterior margin, fine concentric striae are seen in addition to the plications. Concentric striations are present also on the areas below the umbonal ridge; these striations are faint posteriorly, but become sharply defined anteriorly, where they also are more crowded. The valves probably were very thin, since not only the position of the anterior muscular scar, but also that of the anterior part of the pallial line, for a distance of 10 mm., is distinctly indicated. Both the cardinal and the basal margins are curved, the curvature of these margins being approximately equal, the margins being subparallel.

Length 58 mm., height 18 mm., height at beak 16 mm., extension of shell anterior to the beak about 10 mm., convexity of the single valve about 4 mm.

Locality. Type, associated in same rock fragment with *Lophospira beatrice* and *Pterinea demissa;* collected on the Riviere des Hurons, near St. Jean Baptiste, October 1872, by Thomas Curry; preserved in the Paleontological collections of the Geological Survey of Canada, in the Victoria Memorial Museum, Ottawa, Canada. No. 8424.

A second specimen, numbered 2086, is labelled as coming from the Plunk River, at Chambly, Quebec. Although only about 42 mm. in length, it shows the post-umbonal plications very well.

This species is long and narrow, and has the subparallel cardinal and basal margins as in *Orthodesma*, especially that group of species represented by *Orthodesma curvatum*. However, the post-umbonal plications are much more suggestive of some species of *Modiolopsis* belonging to the *Modiolopsis concentrica* group. This form of ornamentation is unknown in *Orthodesma* but is frequent in *Modiolopsis;* for instance in *Modiolopsis arguta* and *Modiolopsis obsoleta*. Compared with these shells, however, the height of the shell is less enlarged posteriorly. If we have not misinterpreted this species it combines the characteristics of two genera, usually easily differentiated.

21. **Orthodesma approximatum,** sp. nov.

(*Plate I, Fig. 5*)

Shell possibly closely related to *Modiolopsis postplicata*, but differing in the absence of conspicuous plications on the post-umbonal slopes. If this species is an *Orthodesma* it belongs to the *Orthodesma curvatum* group. The cardinal margin is slightly curved posteriorly. Excepting near the beak, the umbonal ridge is distinguished only faintly from the general convexity of the shell, and the mesial sulcus is nearly obsolete. The surface is marked by faint concentric striations and wrinkles which are most distinct below and anterior to the beak. Along the post-umbonal slopes, when held in a very oblique light, very faint concentric wrinkles, about 8 or 9 in a length of 5 mm., may be seen, but it is difficult to imagine these as suggesting identity of the form here described as *Orthodesma approximata* with *Modiolopsis postplicata*. The position of the anterior muscular scar and of the adjacent part of the pallial line, for a distance of about 10 mm., is distinctly indicated. The general appearance of the shell is smoothish. From the cardinal side of the umbonal ridge, near the beak, a low angulation extends backward, gradually deviating from the cardinal margin, until at a distance of 30 mm. from the beak it is fully 2.5 mm. from this margin. Above this angulation the surface along the cardinal margin is concave, as though the

cardinal parts of the two valves had been more or less appressed posteriorly.

Length about 50 mm., height 19 mm., height at beak 17 mm., extension of shell anterior to the beak 8 or 9 mm., convexity of a single valve about 5 mm.

Type. From the Richelieu River at Chambly, collected in 1881 by A. H. Foord. Both valves are present but only the right valve is figured. Associated with *Glossograptus quadrimucronatus-approximatus*) in the same rock fragment. Preserved in the Victoria Memorial Museum, by the Canadian Geological Survey at Ottawa, Canada. No. 8425.

22. **Orthodesma nasutum,** Conrad

(*Plate III, Figs. 5 A, B; Plate V, Figs. 3, A, B, C*)

Orthodesma nasutum was described by Conrad from the vicinity of Rome, New York. It occurs, according to Hall, in the arenaceous strata of the higher part of the group, and has not been seen in the underlying softer shales. The figure presented by Hall in the *Paleontology of New York*, vol. I, on plate 81, is from a defective specimen. The original of this figure is preserved in the State Museum at Albany, and is labelled as coming from Lorraine, in Jefferson county. The upper margin anterior to the beak is missing but sufficient is present to indicate that this upper margin was at a distinctly lower level than that part of the cardinal margin which is posterior to the beak. See Fig. 3, on plate V.

According to my own observations *Orthodesma nasutum* is a fairly common species in the upper part of the Lorraine section of New York. It occurs at Bennett's bridge, about a mile down the river from the Salmon River Falls. Here it is associated with *Rafinesquina mucronata*, ordinary flat *Rafinesquina alternata*, *Whiteavesia pholadiformis*, *Byssonychia radiata*, *Lyrodesma poststriatum*, a species closely related to *Ischyrodonta unionoides*, and *Archinacella pulaskiensis*. The overlying layers, half a mile nearer the falls, contain also *Pholidops subtruncatus* but rounded anteriorly as in *Pholidops cincinnatiensis*, *Catazyga erratica*, *Modiolopsis modiolaris*, *Clidophorus planulatus*, and *Cyrtolites ornatus*.

Specimens of *Orthodesma nasutum* occur also about a mile

south of Barnes Corners, associated with *Modiolopsis modiolaris* and *Catazyga erratica*, and at Worthville, but the best specimens were collected about two and a half miles east of Worthville (plate III, Fig. 5 A. B.), in association with *Ischyrodonta* cf. *unionoides*, and it is the first mentioned specimen which forms the basis of the following description. The horizon of the species is distinctly above that exposed at the village of Lorraine, and also above that exposed east of Pulaski. No specimens of *Plectambonites* or *Dalmanella*, so common at the lower horizons, have been noticed here. Although further investigations may result in the finding of these genera also at higher horizons in the Lorraine, they are known to be at least very rare there. In the preceding lists of fossils, the species mentioned as related to *Ischyrodonta unionoides* is the *Ischyrodonta curta* of Conrad.

Species belonging to the group of *Orthodesma curvatum*, Hall and Whitfield, from the Waynesville division of the Richmond, but differing in many particulars. In a specimen about 44 mm. in length, the cardinal margin is only slightly convex for a distance of about 20 mm. posterior to the beak; then it curves more rapidly downward into the very oblique posterior margin. The latter forms an angle of about 35 to 40 degrees with the longitudinal diameter of the shell. Greatest curvature at the lower part of the posterior margin, where it rounds strongly into the only slightly convex basal margin. Near the beak this margin curves upward into the strongly rounded anterior margin. The striking feature of the shell, that which suggested the name *nasutum*, is the distinct dropping of the cardinal margin anterior to the beak. Although this is exaggerated in Hall's figure of *Orthodesma nasutum*, it is nevertheless real. About 8 mm. anterior to the beak this lowering of the upper margin of the shell amounts to fully 3 mm. The umbonal ridge is only weakly defined, and rounds into the general convexity of the shell; the area of greatest convexity lies rather near the cardinal margin posterior to the beak and then curves gradually downward toward the lower part of the posterior margin. Anterior to the beak, the shell is depressed, adding to the nasute appearance of the shell. There is no indication of a mesial sinus. Surface weakly marked by concentric striations, which are most distinct anteriorly, and fairly distinct along the basal margin. Greatest height at midlength, about 15.5 mm.; diminishing to 13 mm. at the beak, owing to the downward curvature of the

cardinal the outline at the beak. Anterior margin of shell fully 12 mm. in front of the beak. Convexity, nearly 4 mm.

23. **Orthodesma pulaskiensis,** sp. nov.

(*Plate III, Fig. 6*)

Basal and cardinal margins subparallel. In a shell having a length of 49 mm. the height at the beak is 13.5, and posteriorly it increases to 15.5 mm. The anterior extremity extends about 10 mm. beyond the beak, and is incurved below the level of the cardinal outline. In the type specimen, a rather angular umbonal ridge extends from the beak obliquely backward, becoming considerably less distinct along the posterior fifth of the shell. This angular umbonal ridge is the most characteristic feature of the type specimen but may not be equally well developed in other specimens belonging to this species. Below this umbonal ridge, and anteriorly, the shell is marked by distinct concentric striae. Above this ridge, on the post-umbonal slope, the concentric striae are far less distinct. The anterior muscular scar is fairly large, and distinctly outlined, but not deeply impressed. From its lower posterior margin, a series of short vertical lines extends obliquely backward, and has some connection with the pallial line. The cardinal margin slopes gradually downward, rounding into the posterior margin, which is most strongly rounded along the lower third of its outline.

Locality. Immediately below the railroad bridge, 1 mile east of Pulaski, New York(plate III. Fig. 6).

The relationship of this form to the *Modiolopsis anodontoides* of Hall (Pal. N.Y. vol. I, pl. 82, Fig. 3a) remains to be determined, but the latter appears to be shorter, with a straighter umbonal ridge, which is more divergent from the cardinal line near the beak. According to a label by Hall, Fig. 3b, pl. 82, the original of *Cypricardites sinuata,* Emmons, "proves to be the young of *Cimitaria recurva,* Hamilton Group."

A form with somewhat similar outline, but with the beak nearer the anterior margin, was found at a considerably higher horizon, in the fossiliferous sandstones, at the cross-roads, one mile south of Barnes Corners (plate III, Fig. 10). The umbonal ridge is not angular, and is distinct only near the beak. In consequence the slopes below the umbonal ridge, toward the basal

margin, and above this ridge, toward the cardinal outline, are not flattened, but have a more evenly convex appearance. The general aspect is that of a *Cymatonota* but there are no oblique wrinkles along the hinge-line.

If *Cymatonota parallela*, Hall, (*Paleontology of New York*, vol. i, plate 82, Fig. 7*c*) did not show the oblique folds along the cardinal line, which are characteristic of *Cymatonota*, the Barnes Corners species might have been compared with that form, although the latter is figured as somewhat shorter. It is evident from the descriptive text that Hall included both forms with and without an oblique carina, and both with and without oblique folds on the cardinal margin in his species, but he placed special emphasis on the presence of the oblique folds along the hinge-line, and only forms possessing these folds can be regarded as typical.

The Barnes Corners specimen resembles most closely the *Orthodesma parallelum*, from Rome, used for Fig. 712, on page 511 of Dana's Manual of Geology, which may be a *Cymatonota*.

24. **Orthodesma prolatum,** sp. nov.

(*Plate I, Fig. 15*)

Hinge-line posterior to the beak apparently straight, meeting the upper part of the oblique posterior margin at an angle of about 120 degrees. Umbonal ridge rather angular, especially toward the beak. The postumbonal slope, between the umbonal ridge and the cardinal margin, is flattened, or, rather, it consists of two flattened areas meeting each other at an angle of about 170 degrees. At the posterior extremity of the shell, this second line of angulation is about 5 or 6 mm. distant from the crest of the umbonal ridge and 4 mm. distant from the cardinal margin. It is not known whether this second line of angulation is a constant characteristic of the species, but, in the single individual at hand, it is noticed that the concentric striae ornamenting the shell become conspicuously more prominent, broader, and more regular, between this second line of angulation and the cardinal margin, than elsewhere on the shell. Of these prominent striae along the cardinal margin there are about 8 in a length of 5 mm. measured transversely to the striae. Elsewhere on the shell the concentric striae are finer and closer, and are accompanied by obscure con-

centric undulations of growth. Although the anterior margin of the shell is not preserved, enough of the shell anterior to the beak is seen to indicate that the concentric striae and obscure undulations are not gathered up anteriorly into a series of strong concentric folds, as in *Rhytimya*, nor are there any obliquely radiating series of granules between the umbonal ridge and the basal margin as in characteristic species of that genus, to which the present form evidently is not related.

Cardinal and basal margins subparallel posterior to the beak, the height being 11.5 mm. at the beak and 13 mm. at the posterior end. The anterior end of the type specimen is defective but enough remains to indicate that it projected about 11 mm. anterior to the beak. Length 38 mm., convexity of single valve about 4 mm.

Locality. Type, associated in the same slab with numerous fragments of a *Strophomena* resembling *Strophomena hecuba*, one good specimen of *Rafinesquina alternata*, one of *Pterinea demissa*, and apparently a fragment of *Catazyga headi;* collected on the beach below Becancour river, and therefore presumably along the St. Lawrence river, October 3, 1852, by James Richardson; forming specimen No. 2144, Palaeontological Collections, Geological Survey of Canada, Victoria Memorial Museum, Ottawa, Canada.

In the subparallel outline of the shell and in the angularity of the umbonal ridge this species resembles *Orthodesma*, but there is no evidence of a conspicuous anterior muscular scar; however only the exterior of the shell is presented. The general aspect of the shell is somewhat like that of *Cymatonota*, but there is no indication of oblique undulations along the cardinal margin, and the umbonal ridge is more angular. Compared with *Modiolopsis postplicata*, both the cardinal and basal margins are straighter, the umbonal ridge is more angular, there is no trace of a mesial sulcus, nor of an anterior muscular area, and the prominent oblique striae along the hinge-line are more numerous.

25. **Cymatonota lenior,** sp. nov.

(Plate I, Fig. 9)

Shell with the general aspect of a Cymatonota but without the oblique wrinkles along the hinge-line, posterior to the beak. The

hinge-line is straight for a distance of at least 37 mm. from the beak, and possibly farther, rounding into the posterior margin of the shell. The latter is rounded. The basal margin is straight as far as a point directly beneath the beak, thence it curves upward toward the anterior margin which is most convex near its junction with the anterior part of the cardinal outline of the shell. The shell enlarges only moderately posteriorly, the basal margin being subparallel to the hinge-line. Umbonal ridge weakly defined even within 15 mm. of the beak, and rounding posteriorly into the general convexity of the shell. Concentric striae most distinct along the anterior parts of the shell, and also along the base; less conspicuous along the posterior border; and rather indistinct along the umbonal ridge and over most of the post-umbonal slope.

Length 70 or 71 mm., greatest height posteriorly 22 mm., height at beak 16 mm., extension of shell anterior to beak estimated at 12 mm., convexity of the single valve about 4 mm.

Locality. Type, collected on the Riviere des Hurons, near St. Jean Baptiste, October, 1872, by Thomas Curry. Preserved in the Victoria Memorial Museum, by the Geological Survey of Canada, at Ottawa, Canada. No. 8422.

26. **Cymatonota pholadis,** Conrad

(*Plate III, Fig. 7*)

In the *Second Annual Report of the New York Geological Survey,* in 1838, Conrad described this species as follows:

> Shell profoundly elongated, ventricose; dorsal and basal margins parallel; posterior sides rugose, or with short undulations near the dorsal margin. Length, $1\frac{3}{4}$ inches.

In describing the next species(*Modiolopsis modiolaris*), he gives the locality for that species as "Pulaski, Oswego county, with the preceding." From this it is evident that the type locality for *Cymatonota pholadis* is Pulaski.

In the *Paleontology of New York,* vol. i, on plate 82, Fig. 6 was published by Hall from a drawing prepared by Conrad, and therefore authentic. Hall states that *Cymatonota pholadis* resembles a new species, *Cymatonota parallela,* occurring "in the soft shaly portions of the group at Pulaski, Loraine, and other places.

I have obtained casts of the same from the ferruginous sandstones in the higher part of the group." The types of the latter are illustrated by Figs. 7*b* and 7*c* on plate 82, and were obtained from Pulaski, in other words from the same locality as the type of Conrad's species *Cymatonota pholadis*. Of the two illustrations of *Cymatonota parallela*, only 7*c* is serviceable in the identification of this species, and this is described in the descriptive matter accompanying the plate as "the left valve, preserving the shell, which is finely striated concentrically, and shows the folds upon the cardinal line." In the text the species is described as having "a few oblique strong wrinkles along the dorsal margin." No consideration need be given in this connection to figures 7*a* and 7*d* on the same plate since these illustrate a species of *Orthodesma* obtained at Cincinnati, Ohio, erroneously referred to the same species. The original of Fig. 7*c* has the relative height and length indicated by the figure, except that the lower part of the posterior margin should be prolonged. The original of Fig. 7*b* is a much better specimen than the published drawing suggests.

In view of the fact that *Cymatonota pholadis* and *Cymatonota parallela* both came from the same type locality, and that specimens referred to the latter are common while no other specimen having the exact dimensions of *Cymatonota pholadis* have ever been found in New York subsequent to the original description, it becomes pertinent to inquire if *Cymatonota pholadis* may not have been an aberrent specimen of *Cymatonota parallela*. In the absence of the type of *Cymatonota pholadis*, which had been lost apparently even before Hall wrote his work, this question can not be answered with absolute certainty, but it is extremely probably that the type of this species was merely a compressed specimen of the species later described by Hall as *Orthonota* (=*Cymatonota*) *parallela*.

Specimens of *Cymatonota* have been collected a short distance below the railroad bridge, about a mile east of Pulaski, in the same rock slab with *Modiolopsis modiolaris*, and *Ischyrodonta unionoides*, and they continue to be found for several hundred yards westward, where they occur associated with *Trinucleus*. A specimen 34 mm. in length had a height of 10.5 mm. near the posterior end, and of 9 to 9.3 mm. at the beak; the anterior margin extends between 6 and 7 mm. anterior to the beak, and the straight cardinal margin reaches 23 or 24 mm. posterior to the

beak. The height of the shell, therefore, increases slightly posteriorly, as might be expected, and the ratio of maximum height to length is about as 3 to 10. The posterior margin is not evenly rounded but is distinctly oblique, making an angle of about 40 degrees with the cardinal margin, while the nearest oblique wrinkles make angles of about 50 degrees. Opposite the posterior termination of the umbonal ridge the rounded outline is more nearly vertical. The greatest curvature is where the posterior outline curves into the basal margin. Umbonal ridge distinctly defined on the cardinal side near the beak, becoming rounded about 15 mm. from the beak and merging into the general convexity of the shell posteriorly. Concentric striations most distinct along the anterior third of the shell, becoming broader and sharply defined posteriorly. Along the umbonal ridge and posterior cardinal slopes, the concentric striae usually are faint. Oblique wrinkles most strongly defined within 13 to 15 mm. from the beak, becoming lower and broader posteriorly.

Specimens of *Cymatonota* of this type have been found, associated with *Trinucleus,* also near the head of the Gulf along the road leading southwest out of the gully toward the school house, about two miles west of Turin (plate III, Fig. 7).

Specimens possessing these characteristics occur at Chambly, along the Richelieu River, in the province of Quebec. A specimen, labelled Chambly Point. R9., is preserved by the Geological Survey of Canada in the Victoria Memorial Museum, at Ottawa, Canada. The handwriting on the label is the same as that on the type of *Whitella complanata,* and the specimen probably was collected by James Richardson. It is illustrated by Fig. 14, on plate I of this *Bulletin,* and is numbered 2085. The following description may be added.

Basal margin straight, nearly parallel to the cardinal margin. Posterior margin oblique. Concentric striae below and anterior to the umbonal ridge. This ridge is distinct anteriorly but becomes more rounded posteriorly. Oblique folds or undulations along the hinge-line conspicuous.

Specimens having the same characteristic occur at the Chambly horizon in the section along the Nicolet River, southwest of Ste. Monique. Here they are associated in the same rock fragments with *Rafinesquina mucronata, Catazyga headi, Pterinea demissa,* and *Lyrodesma poststriatum.* At this horizon *Proetus* also is com-

mon. The range of *Proetus* here is from 533 to 1002 feet below the lowest horizon at which *Strophomena planumbona* and *Rhynchotrema perlamellosa* occur. The specimens of *Cymatonota* just mentioned occur in the upper part of this zone, between 533 and 566 feet below the lowest *Strophomena planumbona* zone. Similar specimens of *Cymatonota* occur also 1699 feet below the lowest *Strophomena planumbona* horizon, in association with *Trinucleus* and *Triarthrus*, and some make their appearance as far up as 50 and 105 feet below the lowest *Strophomena planumbona* horizon.

Cymatonota of the same type occurs also at St. Hilaire; and about 12 miles east of Ottawa, at a road corner reached by going from Vars station three-quarters of a mile westward along the railroad, and then a mile northwestward along the country road.

Among the species described by Ulrich, *Cymatonota pholadis*, as here described, most closely resembles *Cymatonota recta*, from the Fairmount member of the Maysville division of the Cincinnatian, at Cincinnati, Ohio. A full description of *Cymatonota recta*, with notes on *Cymatonota pholadis* and *C. parallela*, is given in the *Geology of Ohio*, vol. vii, p. 662.

27. **Modiolodon poststriatus,** sp. nov.

(*Plate I, Fig. 7*)

Cardinal margin slightly convex, joining the posterior outline, rather abruptly, at an angle of about 65 or 70 degrees. The basal margin diverges from the cardinal margin at an angle of about 15 degrees, rounding rapidly into the posterior margin and into the anterior outline. The umbonal ridge is rather poorly defined in the specimen at hand. The anterior muscular area is strongly defined. Posteriorly, above the umbonal ridge, the shell is strongly marked by striae which are parallel to the posterior margin; of these striae there are about 9 in a length of 5 mm. Elsewhere on the shell there are only faint indications of concentric striae.

Length 35 mm., height posteriorly 20 mm., height at beak 14 mm., extension of shell anterior to beak about 3 or 4 mm.

Locality. One mile west of Vars, along the railroad, and then half a mile northward along the road, associated in the same slab with *Catazyga headi;* collected in 1912 by Aug. F. Foerste. Pre-

served in the Victoria Memorial Museum, at Ottawa, Canada, by the Geological Survey of Canada. No. 8428.

This species probably is closely related to *Modiolodon truncatus*, Hall, and *Modiolodon subovalis*, Ulrich. At least it presents a similar outline, but there is no evidence of the presence of teeth near the beak.

28. **Psiloconcha subovalis,** Ulrich

(*Plate II, Figs. 15 A, B*)

The specimens here described resemble closely the specimen of *Psiloconcha subovalis* figured by Ulrich from the Maysville division of the Cincinnatian section at Morrow, Ohio. The anterior margin is rather oblique as it rounds into the basal margin, and the hinge-line posterior to the beak is straight for about a distance of 21 mm. in a shell 35 mm. long and 17 mm. high, resulting in a rather high shell considering the group of species so far included in the genus. The convexity of the single valve is about 3 mm. Compared with the figures of *Psiloconcha subovalis* the beak is broader and more protuberant, the junction of the umbonal ridge with the cardinal slope is more angular along the distance from the beak halfway toward the posterior margin, the faint mesial depression or flattening is more distinct, and anteriorly the beak is defined more strongly by an oblique angulation almost as strong, although much shorter than the umbonal ridge; moreover, the anterior margin is more regularly rounded. At the beak the shell appears compressed, as though the shell had formerly been more inflated along the umbonal areas.

The specimens here figured were obtained along the Riviere des Hurons, near St. Jean Baptiste, October, 1872, by Thomas Curry, and are associated in the same block with Clidophorus praevolutus and a pygidium of Isotelus. Preserved by the Geological Survey of Canada in the Victoria Memorial Museum at Ottawa. No. 8408.

Shells indistinguishable from *Psiloconcha inornata*, Ulrich, occur half a mile south of the railroad station at St. Hilaire, in a ditch along the road; and a closely similar species occurs a mile and a half northwest of Vars, at a crossing of two country roads.

29. **Psiloconcha sinuata—borealis,** var. nov.

(*Plate II, Figs. 9 A, B, C*)

Specimen about 22 mm. in length, with the hinge-line straight for a distance of about 7 mm. posterior to the beak, and then deflected downward for a distance of about 8 mm. at an angle of about 165 degrees with the hinge-line, before curving rapidly into the rather narrowly rounded posterior margin. Umbonal ridge and mesial sulcus very oblique, and only moderately distinct, but at least much more distinct than in most species of this genus. The umbonal ridge is most distinct within about 5 mm. of the beak, and below this part of the ridge the shell is distinctly flattened, the flattening becoming more concave on following the mesial sulcus toward the basal margin. The latter is comparatively straight but in older specimens might easily become slightly concave. The chief difference between the form here figured and typical *Psiloconcha sinuata*, Ulrich, consists in the anterior outline, which is less quadrate, the hinge-line anterior to the beak being less in line with that posterior to the same, but rather deflected downward as in *Psiloconcha inornata*, Ulrich. Convexity of the single valve fully 2 mm.

As the type of this form has been selected No. 8411 (plate II, Fig. 9*B*) from a group labelled as coming from the Riviere des Hurons and collected October, 1872, by Thomas Curry. Although no separate label was attached to this type specimen it is regarded as unquestionably coming from the same locality as the remainder. It is associated in the same slab with *Clidophorus praevolutus* Fig. 6, plate I. On plate II, Fig. 9*A*, represents the two opened valves of another specimen from the same locality; and bears the number 2087. Fig. 9*C* represents a similar specimen collected by Aug. F. Foerste along the Nicolet River, southwest of Ste. Monique. It occurred somewhere beneath the 80-foot level below the lowest horizon containing *Strophomena planumbona*, at the high river bluff south of the Lower Richmond exposures, and is numbered 8412. In my notes I called it *Psiloconcha sinuata-minima*.

All of the specimens are preserved by the Geological Survey of Canada, in the Victoria Memorial Museum, at Ottawa.

Psiloconcha inornata, Ulrich, is a distinctly flatter shell, with a scarcely ceptibleper umbonal ridge except in the immediate

vicinity of the beak, and with no indication of the mesial sinus. The hinge-line is gently and almost evenly curved downward posteriorly. A specimen of this type, associated with *Catazyga headi, and Pholidops subtruncatus*, occurs among a group of specimens labelled as coming from Chambly. No. 8431.

30. **Cyrtodonta clochensis,** sp. nov.

(*Plate II, Figs. 6 A, B*)

Shell of medium size, obliquely ovate, widest posteriorly; height and length in the ratio of 17 or 18 mm. to 25 mm. with a convexity of 5 mm. in the type specimens, increasing to fully 6 mm. for the single valve in others of the same size. Beaks rather prominent, the umbones rising distinctly above the hinge-line; umbonal ridge rounded, but made more prominent by the flattening of the valves anterior to this ridge. In some specimens this flattening is accentuated to a slightly concave curvature extending obliquely backward fromthe anterior half of the umbones. Surface marked by fine concentric striae. Anterior muscular scar fairly large and rotund. The interior cast here figured exposed the presence of two subequal cardinal teeth which are nearly parallel to the upper anterior margin of the valve; posteriorly there are casts of two long teeth which are subparallel to this margin of the valve.

In outline this shell bears a considerable resemblance to *Cyrtodonta janesvillensis*. It is evident from the growth lines that the lower margin of the specimen here represented by Fig. *6B*, on plate II, originally had the lower margin nearly straight for a distance farther to the rear than here figured, but the beaks and umbonal ridge appear to be much more prominent, and the greatest convexity of the anterior margin appears to be nearer the hinge-line.

Locality. In the lower red clay shales of the Lowville bed along the western shore of La Cloche peninsula, a few feet above the railroad level. Collected in 1912 by Aug. F. Foerste, and preserved in the Victoria Memorial Museum, at Ottawa, by the Geological Survey of Canada. Nos. 8410, 8410*a*.

31. **Ischyrodonta curta,** Conrad

(*Anadontopsis unionoides, Meek, Pal. Ohio, vol. I, pl. XII, Fig. 2*)

(*Plate III, Figs. 14 A, B*)

In the exposures at Bennett's bridge, a mile down stream from Salmon River Falls, a species is quite common which can not be distinguished from *Ischyrodonta unionoides*, from the Fairmount member of the Maysville division of the Cincinnatian. What must be called the basal margin is slightly less convex, so that the angle with the cardinal margin becomes more acute, and the curvature at the anterior margin correspondingly greater. Moreover, the cardinal margin posterior to the beak is straighter, for a distance about as far as the anterior margin extends forward from the beak; in consequence, the angle between the cardinal margin and the posterior is slightly more angular. The oblique lines being accentuated, the shell is slightly less rotund, but the differences are scarcely specific.

The species also occurs at lower horizons, being found within a hundred yards down stream from the railroad bridge, east of Pulaski. At the higher horizon, it occurs also two and a half miles east of Worthville. A similar form occurs two miles west of Worthville.

This shell is so common at some of the upper horizons in the Lorraine, that it could hardly have escaped the attention of the early investigators. It is identical with the *Cypricardites curta* of Conrad, described from a corresponding horizon. The following is the original description, published in the fifth annual volume of the New York Geological Survey, on p. 53, in 1841.

Suborbicular, compressed; hinge margin elevated; posterior margin obtusely rounded. Localities. Near Rome, Oneida county, Richmond, Indiana.

It is the only shell at the Talcott and Comstock quarries, two miles south of Rome, which could be described as SUBORBICULAR. The specimen of *Ischyrodonta curta* figured by Hall (*Paleontology of New York*, vol. I, plate 81) from Grimsby, in Canada, is a very typical form of the species. Fig. 2*a*, on plate 82, however, which may be regarded as the type of Hall's species, *Modiolopsis curta*, is a small individual of *Pterinea demissa*,

from Lorraine, with most of the anterior ear and posterior wing missing. This *Pterinea* probably suggested part of Hall's description: "in specimens not compressed, there is an obtuse oblique carina, extending from the beak to the posterior margin above the base." Since Hall's type proves to be a *Pterinea demissa*, his species evidently has no standing. Figures 2*b* and 2*c* on plate 82 represent two more species included by him under the term *curta*.

32. **Whitella securiformis,** sp. nov.

(*Plate I, Fig. 1*)

Shell rotund quadrangular in outline. The greatest diameter from the hinge-line to the basal margin is 47 mm., while the greatest length is about 55 mm. The outline is strongly rounded both where it turns from the hinge-line posterior to the beak toward the posterior margin, and also from the latter toward the basal margin, but, in a general way, the hinge-line may be said to form an angle of about 110 degrees with the posterior margin, and the latter an angle of about 75 or 80 degrees with the basal margin. Anteriorly, the basal margin rounds evenly into the broadly convex anterior margin. In outline this shell most nearly resembles *Whitella subovata*, Ulrich, but the basal and posterior margins are somewhat straighter and hence the lower posterior part is more angular. The shell is only moderately convex, the convexity of the single valve being about 11 mm. The beak is broken off, but enough remains to indicate that the umbonal ridge was only slightly developed, the angularity between the umbonal parts and the cardinal slope being but poorly defined even in the immediate vicinity of the beak. In other individuals it may have been greater, but it is scarcely likely that in any specimens the strong angularity seen in the majority of the species of this genus, toward the beak, ever was present. The beak probably projected only about 3 mm. beyond the hinge-line. The shell is ornamented by concentric striae which are fainter toward the hinge-line.

Type. From Riviere des Hurons, collected by James Richardson. Listed in the general report on the *Geology of Canada* published in 1863, under the name *Modiolopsis securiformis*, and

preserved in the Paleontological collection, Canadian Geological Survey, Victoria Memorial Museum, Ottawa, Canada. No. 8420. This species was named, but not described or figured, by Billings.

33. **Whitella complanata,** sp. nov.

(*Plate I, Fig. 2*)

Shell originally probably very oblique, with a relatively short hinge-line and anterior margin, and a long basal margin, but at present strongly compressed toward the beak, decreasing the original convexity of the shell, especially along the umbonal areas, and somewhat obscuring the character of its original outline to the beak. Length of the shell along the umbonal ridge, from the beak to the lower posterior margin, 60 mm.; greatest length from front to rear, parallel to the basal margin, 58 mm.; diameter transverse to the latter measurement, 36 mm.; convexity of the single valve in its present compressed condition 10 mm., originally possibly 15 mm.; hinge-line posterior to the beak at least 20 mm., possibly 25 mm. in length. Umbonal ridge forming an angle of about 45 or 50 degrees with the hinge-line, as far as can be determined from the present condition of the specimen. It is quite evident that the umbonal ridge never was conspicuously developed, its convexity being only slightly greater than that of the remainder of the shell, and it never was angular, even near the beak. The beak apparently was broad and the anterior margin extended but moderately beyond the beak. The nearly straight basal margin rounds rather rapidly into the moderately convex posterior margin, the two forming, in a general way, an angle of about 60 degrees. It is evident from the growth lines that this angle becomes more acute with age, and that the length along the umbonal ridge increases more rapidly than any other dimension.

Type. Bearing two labels. One of these is: *Modiolopsis complanata,* Riviere des Hurons, Hudson River group, James Richardson; and the other: Richelieu River, Chambly v. 8. The two localities are by no means identical. In the *Geology of Canada* published in 1863, this species is listed from the Riviere des Hurons. Lithologically, the rock might come from either locality. On the rear of the type specimen, *Lyrodesma poststriatum* is present. The type, numbered 8421, is preserved in the Victoria Memorial Museum, Ottawa, Canada. It was named but not described or figured, by Billings.

The generic reference of this shell to *Whitella* must be regarded as provisional, until further specimens can be collected at the type locality. The absence of a strongly defined umbonal ridge, especially toward the beak, is noteworthy. There is a superficial resemblance to *Cuneamya*. However, there is no evidence of a well defined escutcheon of the form found in *Cuneamya*, nor of an anterior lunule. Moreover, there is no broad, undefined mesial sulcus.

34. **Whitella goniumbonata,** sp. nov.

(*Plate I, Fig. 3*)

Shell small, short, subrhomboidal. Beaks nearly terminal, enrolled toward the hinge-line so as to produce a concave anterior area 11 mm. long along the anterior margin, and 2 mm. in width on the single valve. Present convexity of the single valve about 5 mm. but the original form of the shell probably was more ventricose, producing a more prominent umbonal area and a greater width for the anterior concave area. Umbonal ridge, at its junction with the cardinal slope, angular, the angle being sharply defined from the beak for a distance of about 17 mm. toward the lower posterior angle of the shell, and then becoming more rounded. Concentric striae rather faintly defined.

The hinge area is not exposed in the specimen at hand. The generic determination is based upon the general appearance of the shell. It evidently belongs to the same group as *Whitella obliquata*, Ulrich, but the shell is relatively shorter with a less oblique posterior margin, and with a less oblique umbonal ridge.

Length 24 mm., length from the beak along the umbonal ridge to the lower posterior margin 25 mm.; height posteriorly 20 mm., height at the beak about 17 mm.; extension of the shell anterior to the beak about 2 mm.; convexity of the single valve about 5 mm. in the present state of preservation, originally probably 6 or 6.5 mm.

Type. From the same lot of specimens as those bearing the label Riviere des Hurons, and collected October, 1872, by Thomas Curry, and assumed therefore to come from the same locality, near St. Jean Baptiste, although the specimen here described does not bear a label. Preserved in the Paleontological collections, Geological Survey of Canada, Victoria Memorial Museum, Ottawa, Canada. No. 8426.

35. **Clidophorus planulatus,** Conrad

In the *Fifth Annual Report of the Geological Survey of New York,* published in 1841, Conrad described *Nuculites planulata* in the following terms:

> Compressed; ovate-acute; posterior dorsal margin oblique, rectilinear, extremity acutely rounded; basal margin regularly arched; rib oblique.
> *Locality.* Pulaski, Oswego county.

In the *Paleontology of New York,* vol. i, on plate 82, Figs. 9*a, b, c,* and *d,* all represent specimens of *Clidophorus planulatus* collected at Turin. Of these, the specimens represented by Fig. 9*a* are embedded in an arenaceous slate, associated with *Trinucleus concentricus, Zygospira modesta,* round and pentagonal columnals of crinoids, as at the type locality immediately east of Pulaski, along the river.

The following is a description of specimens collected by the writer at the type locality, along the river east of Pulaski, New York.

Shell transversely elliptical oblong, height about half the length of the shell, with the beak approximately a third of the length of the shell from the anterior end. Umbonal ridge low, distinctly defined along its cardinal border where it makes an angle of 162 to 165 degrees with the longitudinal axis of the shell. Above this umbonal ridge, the posterior cardinal slope of the shell is flattened and subalate. The posterior part of the hinge-line extends from the beak for a distance equalling about two-fifths of the length of the shell, and then makes an angle of about 150 degrees with the posterior margin of the shell. The margin is rather strongly rounded at both the posterior and anterior ends of the shell, the maximum curvature of the anterior margin, however, being nearer the hinge-line. The basal margin is moderately and evenly convex. The clavicular adductor support anterior to the beak forms an angle of about 80 degrees with the longitudinal axis of the shell; it is comparatively straight and extends downward to about the middle height of the shell; it is sharp and narrow, appearing on the cast of the interior of the shell as a sharp incision not depressing the immediately adjoining part of the shell. The convexity of the shell is moderate, that of a shell 9 mm. in height being about 1.6 mm. Specimens 20 mm. in length occur. Com-

pared with the specimens figured by Hall from Turin, the Pulaski forms are relatively longer and hence are more convex along the anterior and posterior outlines.

It will be noted that all of the specimens of *Clidophorus planulatus*, from Turin, were figured by Hall as having more oblique clavicular adductor supports anterior to the beak. Figs. 9*b*, *c*, *d*, represent specimens imbedded in the shale. Of these, only specimen 9*d* presents a very oblique clavicle, approximately 55 degrees, while the original of Figs. 9*b* and 9*c* show angles as steep as 75 to nearly 80 degrees. Fig. 9*a*, although described as coming from arenaceous slate, may have come from about the same horizon as the shale specimens, since thin arenaceous layers often are interbedded in the Lorraine shale. This horizon may be lower than that of the type locality, in the river bed east of Pulaski. It is evident from the figure that the rock fragment contained also *Trinucleus*, *Zygospira*, and columnals of *Heterocrinus* and *Glyptocrinus*. Similar specimens, with more oblique clavicular adductor supports occur also at Rome, New York. One of these specimens, taken from the series numbered R–1232 in the State Museum, at Albany, New York, is here represented by Fig. 13, on plate I. It is not certain, however, whether these specimens with the more oblique clavicular adductor support impressions should be regarded as distinct from the forms with more vertical impressions. Occasional specimens from the type locality, east of Pulaski, also have very oblique clavicular adductor supports, forming angles of 65 degrees with the longitudinal axis of the shell. This angle may vary in different individuals of the same species.

36. **Clidophorus praevolutus,** sp. nov.

(*Plate I, Fig. 12, type; two figures under 6, cotypes*)

Transversely elliptical; length 11.5 mm.; height 5.2 mm.; ends narrowly rounded. Anteriorly the shell extends 3.5 mm. in front of the beak; here the cardinal outline is comparatively straight and forms an angle of about 165 degrees with the hinge-line back of the beak. Posteriorly there is a narrow concave subalate cardinal slope, scarcely a millimeter wide at its posterior end; along this part of the shell the hinge-line is straight for a distance of about 5 to 6 mm. and then joins the upper part of the posterior margin

at an angle of about 120 to 125 degrees. Surface marked by fine concentric lines, not readily seen except under a lens. Cast of interior with a narrow, slightly sigmoid, clavicular adductor support impression just in front of the beak, forming an angle of 65 degrees with the longitudinal axis of the shell, and extending about 2.5 mm. from the tip of the beak. Anterior to this clavicular support groove a shallow depression extends across the shell from the beak to the anterior part of the basal margin at an angle of about 55 degrees with the longitudinal axis. Anteriorly this shallow depression is bounded by a low transverse ridge or fold, also extending from the beak toward the anterior part of the basal margin, at an angle varying from about 45 degrees near the beak to 50 degrees near the basal margin. It is the shallow depression and low ridge or fold anterior to the clavicular support impression in the cast which are regarded as most typical of the form here described.

Type. Richelieu River, near Chambly, collected by A. H. Foord in 1881. No. 2079, in Paleontological collections, Geological Survey of Canada, Victoria Memorial Museum, Ottawa, Canada. Associated with *Glossograptus quadrimucronatus-approximatus*, and *Rafinesquina alternata*. The type is represented by Fig. 12 on plate I.

The two specimens represented by Fig. 6 on the same plate are regarded as belonging to the same species. They occur on the rear of the rock fragment containing the type of *Psiloconcha sinuata-borealis*. This fragment came from a group labelled as coming from the Riviere des Hurons, and as collected by Thomas Curry, in October, 1872, but no label is attached to the fragment itself. No. 8427.

All of the figures are unsatisfactory, owing to the small size of the specimens. The engraver did not preserve well the outlines of the valves although these were clearly shown in the photographic reproduction on the copper plate. Compared with *Clidophorus planulatus*, the valves are relatively lower and longer, and the clavicular adductor support is more oblique, although the amount of this obliquity apparently is a variable feature.

Specimens resembling *Clidophorus praevolutus* occur also half a mile south of the station at St. Hilaire, in a ditch along the road.

37. **Ctenodonta lorrainensis,** sp. nov.

(*Plate III, Figs. 8 A, B*)

Shell rotund in outline, the length and width being about equal. The outline, however, is not strictly circular, there being a slight tendency toward angulation at the posterior extremity, owing to a straightening of the posterior part of the arcuate hinge-line, as in *Ctenodonta pectunculoides*, Hall, from the Mt. Hope and Fairmount beds of the Maysville division of the Cincinnatian, at Cincinnati, Ohio. In the latter species, however, the tendency is toward a greater length than height of the valves, while in *Ctenodonta borealis*, the tendency is toward a slightly greater height than width. This results in a less angulate posterior outline. Moreover, the height of the hinge area, compared with the rest of the shell, is less. Surface with very fine concentric striae, readily seen only under a lens.

Ctenodonta cingulata, Ulrich, was described from the Gasteropod layer at Marble Hill, Indiana. This is a layer several feet thick, and about 65 feet above the horizon at which *Leptaena richmondensis-precursor*, and *Dinorthis carleyi*, the characteristic fossils of the middle part of the Arnheim, occur. Ten feet below this Gasteropod layer, at Scott Hill, in Trimble county, Kentucky, there is a horizon full of *Tetradium* and *Stromatocerium*, immediately overlying a zone, about 15 feet thick, in which *Homotrypella hospitalis* is common. This gasteropod layer is regarded as belonging to the lower part of the Waynesville section, although the characteristic brachiopod fauna of the Richmond is found in this part of Indiana and Kentucky only at a considerable distance above the Gasteropod layer. Compared with *Ctenodonta lorrainensis, Ctenodonta cingulata* is larger, has a much thicker shell, the hinge area is higher, especially at the beak, and the teeth here are much longer, narrower, and more crowded.

Ctenodonta pulchella, Hall, was described from the black slate near Watertown, New York. This black slate is interbedded with the limestone at the base of the Trenton section. The specimen represented by Figs. 12*a*, *b*, on plate 82, of vol. I, *Paleontology of New York*, is listed as number 1064 in the collections of the American Museum of Natural History. This species, judging by the published figure, is readily distinguished from

Ctenodonta lorrainensis by the relatively greater length of the shell, compared with its height.

Locality. *Ctenodonta lorrainensis* occurs along the creek, northeast of the bridge at the eastern edge of the village of Lorraine, New York. The same species is even more abundant where the road to Worthville crosses the creek, two miles west of Worthville, and since the latter are best preserved, they are chosen as types.

Similar nearly rotund specimens of *Ctenodonta* occur in Canadian strata referred to the Lorraine. The valves appear to be slightly more convex; the hinge area, a little higher; and the teeth a little stronger and more erect, but the differences are slight. An excellent cast of the interior, numbered 2083, was collected on the Richelieu River, at Chambly, in 1881, by A. H. Foord. It is associated in the same rock fragment with *Pholidops subtruncatus, Protowarthia cancellata, and Glossograptus quadrimucronatus-approximatus.* Similar specimens occur at St. Hilaire in the ditch along the road leading off southeastward from the station. The exposures are about half a mile distant from the railroad.

38. **Lyrodesma poststriatum,** (Emmons) Hall

(*Paleontology of New York, vol. I, Plate 82, Figs. 10 A, B, 1847*)

Lyrodesma poststriatum was figured by Emmons among Utica fossils from Jefferson county, apparently because he had found this species associated with *Triarthrus.* If so, he found his type at a much lower horizon than the large specimen figured by Hall, from Pulaski, a short distance south of that county. At Pulaski it occurs beneath the railroad bridge and also at the *Trinucleus* horizon, several hundred yards west of the bridge. It occurs northeast of the bridge within the limits of the village of Lorraine; also at Worthville, and two miles west of Worthville, where the road to Lorraine crosses a creek. It is found at a higher horizon at the power house at Bennett bridge, a little over a mile west of Salmon River Falls, and also half a mile eastward, a short distance below the level of the base of the falls.

In the large specimen figured by Hall, the upper part of the anterior outline is more rotund; apparently four simple plications occur above the umbonal ridge, followed by several fascicles of

finer striae. The specimen is not properly cleaned and the figure needs republication.

In the province of Quebec, the same species occurs at several localities in the Lorraine between Ottawa and Vars; also on the Richelieu River at Chambly, and two miles northwest of St. Hugues on the Yamaska River.

Lyrodesma plana was described by Conrad from the fossiliferous sandstones at the base of the Oswego sandstone section, near Rome. The types have been lost and no specimens have been discovered since the original description was published.

39. **Rhytimya oehana,** Ulrich

(*Plate I, Fig. 11*)

The shell is strongly compressed, the thickness from valve to valve being scarcely more than 4 mm.; original thickness unknown. Basal margin slightly concave, the mesial sulcus practically obsolete, the surface anterior to the umbonal ridge being flattened rather than depressed. Posterior outline, at the end of the umbonal ridge, angular rather than rounded. Surface strongly striated and wrinkled concentrically, the wrinkles being increased to strong folds anteriorly. Above the umbonal ridge the wrinkles become faint but the striae remain distinct. The characteristic oblique rows of punctae or granules may be detected from the anterior fourth of the shell to the umbonal ridge posteriorly.

Locality. Richelieu River at Chambly, associated in the same rock fragment with *Catazyga headi*, *Pholidops subtruncatus*, and *Cleidophorus praevolutus*. Collected in 1912 by Aug. F. Foerste. Preserved at the Victoria Memorial Museum, at Ottawa, Canada, by the Geological Survey of Canada. No. 8423.

40. **Cuneamya scapha—brevior,** var. nov.

(*Plate II, Fig. 12*)

Shell closely related to *Cuneamya scapha*, but relatively shorter, and hence with a less inclined umbonal ridge and mesial sulcus. The angle between the umbonal ridge and the hinge-line is approximately 45 to 50 degrees, the median part of the mesial sulcus forming an angle of about 70 degrees. The mesial sulcus has a

width of about 15 mm. near the basal margin, and is distinct even close to the beak, although this may be only an individual characteristic. The beak is broader and far less acute than is indicated in the figure of the type presented in the second volume of the Paleontology of Ohio. The anterior outline, however, is closely similar. The umbonal ridge is rounded, not angular, and the posterior margin is more evenly rounded posteriorly. Concentric striae or low narrow undulations fairly distinct anteriorly, becoming fainter along the umbonal ridge and on the cardinal slope.

Length 32 mm.; height at posterior end 18 mm.; height at beak 20 mm.; extension of shell anterior to beak about 3 or 4 mm.; length of lunule about 7 or 8 mm.

Type of the variety here described: Riviere des Hurons, near St. Jean Baptiste, collected October, 1872, by Thomas Curry. Preserved in the collections of the Geological Survey of Canada, in the Victoria Memorial Museum, at Ottawa. No. 8407.

Specimens apparently identical with *Cuneamya brevior* occur half a mile south of St. Hilaire station, in a ditch along the road, a mile and a half northwest of Vars at a crossing of two country roads. Along the Nicolet River, southwest of Ste. Monique, in the lower part of the Proetus chambliensis zone.

41. **Archinacella clochensis,** sp. nov.

(Plate II, Figs. 5 A, B)

Among described species, this form most nearly approaches *Archinacella orbiculata*, Hall, from the lower Trenton or Snake Hill shale of eastern New York, and *Archinacella subrotunda*, Ulrich and Scofield, from the Ctenodonta bed of the Black River group in Minnesota.

Shell suboval, about 13 mm. long, 11 mm. wide, and slightly over 4 mm. high. Obliquely subconical, with the apex about 1 or 1.5 mm. vertically back from the anterior margin. In profile view, moderately concave between the apex and the anterior margin, and rather evenly convex between the apex and the posterior margin. The area of highest elevation is not at the apex but about 3 mm. posterior to the same. This profile view agrees most closely with that presented by Ruedemann of one of the types

of *Archinacella orbiculata*, Hall,[4] but the beak is less incurved, the concentric striations are finer, and there is an absence of the stronger, nearly equidistant lines of growth shown by both of Hall's types. Compared with *Archinacella subrotunda*, the shell is distinctly longer. The form here described from the Lowville is probably an undescribed species.

Locality. From the basal red clay shales of the Lowville, on the western shore of La Cloche peninsula, a short distance above railroad level. Collected in 1912 by Aug. F. Foerste, and preserved in the Victoria Memorial Museum, at Ottawa, by the Geological Survey of Canada. No. 8418.

42. **Archinacella pulaskiensis,** sp. nov.

(Plate III, Figs. 3 A, B, C, D)
Paleontology of New York, vol. i, Plate 83, Figs. 7a, 7b

The form figured by Hall from the Lorraine at Pulaski, New York, as *Archinacella patelliformis*, differs in outline from his Trenton types, which were derived from the dark, compact, Trenton limestone at Middleville, New York. This shell is broader and more convex along the middle and the outline, therefore, is rather broadly ovate than ovate oblong. Otherwise the two shells are closely similar. The beak extends almost or fully as far forward as the anterior margin of the shell. It overhangs this margin by an anterior slope which on lateral view is not so strongly concave. The beak is rather pointed, especially when viewed from above, and there is a tendency toward carination for a moderate distance posterior to the beak. The highest part of the shell is about five-twelfths of the length of the shell from the anterior margin. The shell is smooth, surface striations being faint or absent.

The type of the species occurs in the same rock with *Modiolopsis modiolaris*, *Byssonychia radiata*, *Hormotoma gracilis*, *Dalmanella*, and *Glyptocrinus* columnals.

This species occurs at the *Trinucleus* horizon, several hundred yards west of the railroad bridge across the river, east of Pulaski. It is found also northeast of the bridge within the limits of Lorraine village, and along the creek within the boundaries of Barnes

[4] The Lower Siluric Shales of the Mohawk Valley, *Bulletin 162 of New York State Museum*, plate 7, Fig. 6.

Corners. It is found also at the power house at Bennett Bridge, a little over a mile west of the Salmon river Falls.

The same species occurs in the province of Quebec, on the Richelieu River at Chambly. (No. 8434, in Victoria Memorial Museum, Ottawa, Canada.) A similar form is found on the Nicolet River, southwest of Ste. Monique, about 575 feet below the lowest horizon containing *Strophomena planumbona*.

The type of *Protowarthia cancellata*, Hall, was obtained at Lorraine; *Cyrtolites ornatus* was described by Conrad from Washingtonville, from a horizon approximately equivalent to that at the railroad bridge east of Pulaski. The types of *Hormotoma gracilis* and *Clathrospira subconica* were obtained from the Trenton at Watertown.

43. **Lophospira beatrice,** sp. nov.

(*Plate II, Figs. 8 A, B*)

The *Murchisonia beatrice*, Billings, listed in the *Geology of Canada* in 1863 from the Riviere des Hurons is as good a species of *Lophospira* as many another form of this genus, although undoubtedly closely related to *Lophospira bowdeni*, Safford. The specimens figured by Safford represent one extreme of development, with apical angles of 27 to 30 degrees, and with 8 to 10 volutions of which 6 or 7 are usually preserved, the tip being broken off. The characteristic feature of this group of shells is the rather broad and convex peripheral band, situated slightly below the center of the whorl, varying considerably in prominence but usually far less angular than in most species of this genus. Upper slope flattened or moderately concave toward the peripheral band, angulated or obscurely carinated where it curves into the rather deep sutural area. The lines of growth are strongly recurved toward the peripheral band, which they cross as rather broadly concave lines, indicating a rather broad notch in the outer lip. There are no raised lines or striae bordering the upper and lower parts of the peripheral band, as in so many species of the genus. A lower carination or angulation usually obscure but sometimes fairly distinct, ending near the upper margin or the inner lip, is seen on the last volution of some specimens. The aperture is not well preserved in any specimens at hand but enough is preserved to indicate that it had essentially the same form as

that of *Lophospira bowdeni*. The chief difference between *Lophospira beatrice* and typical *Lophospira bowdeni* consists in its larger apical angle, apparently averaging about 35 degrees but varying from 30 to 38 degrees. This produces a shorter shell, so that the greater number of specimens, in their present state of preservation, present only four or five volutions although the complete shells probably possessed seven or eight.

The types formed part of a small group of shells in a small tray in the collections of the Geological Survey of Canada, at the Victoria Memorial Museum, at Ottawa, Canada. They were accompanied by the original printed label used for the Billings types, bearing the following information: *Murchisonia beatrice*, Billings. Riviere des Hurons. Hudson river group. Collected by James Richardson. 8A is numbered 8417; 8B, 8417*a*. This species was named, but not described or figured, by Billings.

Similar, if not identical forms, exist in the Richmond exposures three-fourths of a mile west of Vars, and also along the Nicolet River, southwest of Ste. Monique. They were not detected in the great Lorraine section, along this river.

44. **Ruedemannia abbreviata,** Hall

The species described by Hall as *Murchisonia uniangulata*, variety *abbreviata*, in the *Paleontology of New York*, vol. I, page 304, belongs to the Robusta section of the genus *Lophospira*, as divided by Ulrich in his Monograph on the Lower Silurian Gasteropoda of Minnesota. The type of *Lophospira abbreviata* was found at Pulaski, in rock containing *Calymene*, *Orthoceras* with transverse striae as in *Orthoceras lamellosum*, *Cyrtolites ornatus*, *Hormotoma gracilis*, *Byssonychia radiata*, and the common Lorraine form of *Dalmanella*. Apical angle between 60 and 65 degrees. The transverse striae form a strongly reëntrant angle toward the peripheral band. This band is tricarinate, or trilineate; in typical specimens, the middle line is scarcely more prominent than the other two; the intermediate spaces are concave. The slope of the whorl above the peripheral band is gently convex excepting in the immediate vicinity of the band where it is gently concave. That part of the whorl which is below the peripheral band is evenly and somewhat more strongly convex. Since two specimens are present on the same rock fragment,

numbered 1136–1, in the American Museum of Natural History, in New York, I have chosen the one showing the trilineate peripheral band to best advantage as the type, since this specimen unquestionably furnished the material for Fig. 2*c* on plate 83, accompanying Hall's description. A third specimen occurs in the same rock as what I regard as the type of *Ormoceras crebriseptum*, namely figure 2*b*, on plate 87. The vertical striae of this *Ormoceras* belong only to the exfoliated interior of the shell, and the appearance of the surface is unknown. The trilineate peripheral band of the *Lophospira abbreviata* is well shown, and there is a trace of a revolving angulation very much farther down than in *Lophospira lirata*, Ulrich. There is no trace of an angulation on the upper slope.

Shells of this type, with subrotund whorls and trilineate peripheral bands, the three lines nearly subequal, appear sufficiently distinct from the typical forms of *Lophospira* to receive a distinct designation. For this reason the term *Ruedemannia* is here proposed, in honor of Dr. Rudolph Ruedemann, as a slight recognition of his monumental labors on Paleozoic fossils. As a type of this genus, *Lophospira lirata*, Ulrich, from the Eden formation at Cincinnati, has been selected, because the New York species here described appears more closely related to the *Lophospira lirata* of Ulrich than to the *Pleurotomaria robusta* of Lindstroem. The presence of revolving striae is not regarded as essential. I assume, in the absence of further data, that the *Lophospira lirata* of Ulrich is identical with the *Pleurotomaria ohioensis* of James, a species from the Cincinnatian of Ohio, but from a horizon not designated by the author. The type of *Lophospira lirata*, Ulrich, forms No. 45904 in the collections of the U. S. National Museum.

45. **Pterotheca** *cf.* **attenuata,** Hall

(Plate II, Fig. 3)

A small species of *Pterotheca*, apparently belonging to the Pterotheca attenuata group. Lateral margins gently convex, rounding more strongly into the posterior and anterior margins, resulting in a rounded quadrangular outline. Shell moderately convex, excepting at the carina which rises strongly above the general convexity of the shell. In a specimen 20 mm. wide and

17 mm. long, the general convexity is about 3 mm., but the anterior part of the carina rises nearly 4 mm. above the neighboring parts of the shell. The shell is concentrically wrinkled and striated, but these markings are not very conspicuous. The lateral lines of attachment of the septum are distinctly indicated and are illustrated by the accompanying figure.

Locality. In the basal red clay shales of the Lowville, along the western shore of La Cloche peninsula, several feet above railroad level. Collected in 1912 by Aug. F. Foerste, and preserved in the Victoria Memorial Museum, at Ottawa, Canada, by the Geological Survey of Canada. No. 8406.

46. **Pterotheca pentagona,** sp. nov.

(*Plate II. Figs. 1, 2*)

Shell symmetrical, moderately convex, at least in the present state of preservation, excepting close to the apex where the curvature of the shell toward the posterior margin is more pronounced. Posterior margin nearly straight or only moderately curved for a distance of 10 or 12 mm. on each side of the apex, and then curving forward toward the lateral margins of the shell. Lateral margins nearly parallel, converging from a width of 48 mm. at the rear to 40 mm. toward the front, where the lateral margin forms another angle, curving inward toward the median part of the shell. A fifth angle is formed anteriorly, where the margin curves forward on approaching the median wing or carina. The length of the shell from the apex to the anterior part of the carina is at least 35 mm. and possibly 37 mm. The antero-lateral angles are estimated as about 28 mm. anterior to a line drawn transversely through the apex.

Only the basal part of the carina along the anterior half of the shell is preserved. This suggests the presence of a carina at least 10 mm. in height, and possibly higher. The shell is finely striated concentrically, the striae following the lateral and anterior outlines of the shell; at the base of the carina they curve backward and upward suggesting a vertical slit anteriorly. In addition to the striae, the shell also is concentrically wrinkled, the wrinkles being best developed between the apex and the lateral margins. The lower side or aperture is partly traversed by a broad triangular septum, with its apex at the apex of the shell, and with its

sides attached to the main body of the shell along straight or moderately curved divergent lines, forming an angle of about 75 degrees with each other, this angle becoming more acute near the apex. The lines of attachment are about 20 mm. long, equalling from two-thirds to three-fourths the length of the shell from the apex to the antero-lateral angles. The striae upon the inner surface of this septum indicate that its anterior edge was moderately convex. Seen from the lower side of the shell, the septum was moderately concave; at the apex the shell is only moderately incurved. Convexity, aside from the dorsum, estimated at 5 to 7 mm., but the shell may be more or less vertically compressed as it lies in the rock.

Type. Richelieu River, near Chambly, collected 1881 by A. H. Foord. No. 2155, Paleontological collections, Geological Survey of Canada, Victoria Memorial Museum, Ottawa, Canada. Fig. 1, on plate II.

Another specimen, plate II, Fig. 2, referred to *Pterotheca pentagona*, was found by the writer on the Nicolet River, southwest of Ste. Monique. This specimen occurred associated with a variety of *Leptaena rhomboidalis*, *Rafinesquina mucronata*, *Catazyga erratica*, *Proetus*, and numerous other species, at a horizon 820 feet below the lowest strata in this section in which *Strophomena planumbona* and *Rhynchotrema perlamellosa* are found. *Trinucleus* and *Triarthus* occur 730 feet below this *Pterotheca pentagona* horizon. This second specimen also is preserved in the Victoria Memorial Museum, and is numbered 8409.

Pterotheca transversa was described in 1852 by Salter, under the term *Cleodora transversa*, in the *Report of the British Association* for 1851, on page 64, from Desertcreat, Tyrone, in Ireland. With this species the Canadian form has been erroneously identified.

47. **Cornulites,** sp.

At the *Strophomen nasuta* and *Trinucleus* horizons, between the railroad bridge, about a mile east of Pulaski, and a point several hundred yards westward, down the stream, there is a form of *Cornulites* with a free habit of growth, and practically straight or only slightly curved. These straight forms are known usually as *Tentaculites*. At the initial tip it probably was attached to some other organism, but no evidence of such attachment was

found. The tubes are crossed by annulations, which are rather angular on the crest, sloping with about equal rapidity into the concave constrictions both above and below each annulation. Tube very thin, the interior cast also annulated; annulations sloping gradually in the distal direction, and abruptly on the proximal side; in fact, on the proximal side these annulations often are slightly incurved. Exterior with very fine and numerous longitudinal striations, often alternating slightly in size. At each annulation these longitudinal striae begin as very fine striae on the distal side of the crest, dip into the constricted parts, and become stronger on rising up the proximal slope of the next annulation. Of these longitudinal striae there are about 8 or 9 in a width of 1 mm. around the circumference, with an equal number of still finer, intermediate ones, visible under a lens in specimens preserved in fine grained strata. Transverse striations are present in some specimens, but can be seen only with a magnifier and under strong cross illumination. The length of the specimens at hand scarcely exceeds 15 mm. This is the species figured by Hall on plate 78 of the *Paleontology of New York*, in vol. I.

Two miles west of Worthville, on the road to Lorraine, another form occurs associated with *Trinucleus* and other fossils suggesting a fauna very similar to that east of Pulaski. In this form of Cornulites the annulations also are rather sharp along the crest, but they tend to slope more rapidly on the distal than on the proximal side. Their chief characteristic, however, is the coarseness of the longitudinal striae, which become so strong on ascending the proximal slopes that they give an almost nodular or scalloped appearance to the crest of the annulations. Of these nodules there are about 5 in a width of 1 mm. around the circumference. Under strong cross illumination very fine intermediate longitudinal striae can be seen, a single node sometimes representing the distal termination of two or even three striae. Transverse striae are readily distinguished under a lens in some specimens.

Although the two forms here described present quite a different general appearance, the second may be only a more vigorous form of the first, and a much more extended study is necessary to determine their degree of relationship.

In referring these tubes to *Cornulites*, the writer has merely followed Hall.[5] Cornulites flexuosa, Hall, was founded on a form

[5] *Paleontology of New York*, vol. vii, p. 8 of Supplement.

from the Trenton limestone, at Lowville, New York. I have been unable to identify either form, with certainty, with described species from Cincinnatian rocks, and the descriptions here given are intended merely to call attention to the chief characteristics observed, with the view of further collecting.

48. **Technophorus punctostriatus—quincuncialis,** var. nov.

(*Plate II, Figs. 13 A, B*)

The shell or carapace of the minute crustacean here called *Technophorus quincuncialis* so closely resembles that of *Technophorus punctostriatus*, Ulrich, that it can be best described by noting the differences. If a line be drawn vertically downward from the beak toward the basal margin, then the basal margin of *Technophorus quincuncialis*, posterior to this line, will be found to be more convergent with the dorsal margin, forming an angle of about 10 degrees with a horizontal line. Moreover, the two sigmoid ridges crossing the posterior half of the carapace, from the beak toward the lower part of the posterior margin, are more oblique, the anterior one forming an angle of about 40 to 43 degrees with a horizontal line; the convex part of the curve near the beak is relatively much longer, and the concave part, toward the postero-ventral angle, is correspondingly shorter. Only one specimen, among those at hand, shows the character of the ornamentation between the two sigmoid ridges, and in this case it consists of striae, about 3.5 in a width of half a millimeter; these striae are much wider than the concentric striae on the main body of the carapace but occur at about the same intervals as the concentric striae where the latter are most distant from each other on the anterior part of the body; in direction, they form angles of about 55 degrees with a horizontal line, or about 15 degrees with the general trend of the anterior sigmoid ridge, in this respect resembling *Technophorus divaricatus* rather than *Technophorus punctostriatus*. The posterior or cardinal wing, behind the second sigmoid ridge, bears no ornamentation of any kind on any of the specimens at hand. The interior ridge or so-called clavicle extending from the anterior part of the beak toward the basal margin is 2 mm. in length. Its position frequently can be detected on the exterior of the carapace. Along the upper part of the body, between the clavicle and the anterior sigmoid ridge, the

concentric striae ornamenting the exterior are approximately horizontal, but ventrally from this part of the body, the concentric striae become parallel to the lower margin. Anterior to the anterior sigmoid ridge, for distances varying from 1.5 mm. toward the dorsal margin, to 2.5 mm. near the middle, and from 5 to 6 mm. near the basal margin, the spaces between the concentric striae are crossed by short transverse striae which are more closely crowded toward the sigmoid ridge, but become more distant anteriorly; over the central parts of the main body the ornamentation takes more of the nature of circular or rounded hexagonal pits having a quincuncial arrangement. Directly below and in front of this quincuncially ornamented area, however, within seven-tenths of a millimeter of the ventral and anterior margins, only the concentric striae are distinctly indicated.

Type. Chambly, Richelieu River, collected in 1881 by A. H. Foord; No. 8415. The same slab contains also specimens of *Pholidops subtruncatus*, Hall, and a free cheek of *Proetus chambliensis*. A second specimen, No. 8413, from the same locality, came from a layer containing an abundance of *Plectambonites rugosa*, Meek, associated with *Catazyga headi*. A third fragment of rock, numbered 2076, contains not only the *Technophorus*, but also *Pholidops subtruncatus* and *Byssonychia radiata*. A fourth specimen, displaying chiefly the interior characters of the carapace, shows the perpendicular ridge called the clavicle in the preceding description. The accompanying illustrations are not adequate for presentation of the characteristics of this species.

It is probable that all of the species of *Conocardium* described from Ordovician strata are to be regarded as crustaceans. This is true certainly of *Conocardium* (*Pleurorhynchus*) *antiquum*, Owen, *Conocardium elegantulum*, Billings, and *Conocardium richmondensis*, Foerste. None of these shells have a true beak or hinge area as in lamellibranchiata, and they form a new genus of crustaceans. *Conocardium immaturum*, Billings, probably represents a second new genus of crustaceans.

49. **Cryptolithus tessellatus,** Green

In his description of *Trinucleus concentricus*, Hall states that: "The specimen figured by Green, is one before referred to, as coming from the slates of the Hudson-river group, near Waterford, which at that time were regarded as almost non-fossil-

iferous." Moreover, Green himself, in his *Monograph of North American Trilobites*, states: "Mr. Eaton says that *Nuttainia concentrica* 'occurs in the wacke variety of transition of argilites on the Champlain canal,' between the town of Waterford and the Mohawk river. The specimen in my cabinet, from which our cast was made, is from that place."

The rather meager fauna so far discovered at Waterford has been found, by Dr. Rudolf Ruedemann, to belong stratigraphically to the Snake Hill beds, which at the type locality, on the east side of Saratoga Lake, contain a much larger fauna, placed by Dr. Ruedemann near the base of the Trenton, below the Canajoharie shale.

It is scarcely likely that the *Trinucleus* found in the Pulaski division of the Lorraine belongs to the same species as this Snake Hill form, but no material is at hand by means of which the two forms may be discriminated.

The following is a description of a series of specimens occurring in a single block of finegrained Lorraine rock from which most of the lime had been dissolved, leaving the specimens in the form of of casts of the upper and lower surfaces of the cephalon.

Glabella obovate, tumid in front, becoming lower and narrower posteriorly; at the posterior margin of the cephalon its width is equal to half, or slightly less than half the width of the glabella anteriorly. Here the posterior end of the glabella is crossed by the nuchal furrow in a direction convex to the rear, posterior to which the glabella extends with a rounded V-shaped outline, projecting behind the posterior margin of the cephalon a distance about equal to the width of the glabella at this margin. Posteriorly, this nuchal V-shaped segment of the glabella terminates in a sharp narrow spine about 2 mm. in length, always present, but generally overlooked. On each side of the posterior part of the glabella, in the nuchal groove, and also a very short distance anteriorly, there is a small depression or pit which is the only evidence of segmentation shown by the glabella. The glabella rises an amount equal to almost half its width above the general convexity of the cheeks. The latter are moderately convex over most of their surface, becoming slightly tumid only laterally, where they adjoin the pitted border. A narrow groove separates the cheeks from the equally narrow raised posterior border of the cephalon. For two-thirds the width of the cheek, the posterior

border of the cephalon is directly at right angles to the longitudinal axis of the cephalon, and then curves diagonally backward toward the genal spines. The pitted area extends, from the pitted lateral border, around the postero-lateral part of the cheeks almost as far as the point at which the posterior border of the cephalon begins to curve diagonally backward. Anterior to the glabella there are four concentric rows of pits, which remain distinct as far as a point opposite the posterior margin of the free cheeks. A fifth row is intercalated between the third and fourth rows from the front, at a point almost directly in front of the middle of the cheeks, and a sixth row is intercalated between the fourth row and the cheeks, a little anterior to the mid-length of the latter.

The first two rows of pits, counting from the anterior margin, may be distinguished from the remainder by the fact that for about two-thirds of the width of the cephalon the pits of these two rows are vertically in front of each other and the line of separation between the members of each pair depressed, so that here the pitted border consists of a lateral succession of pairs of pits sunk into a common depression. Specimens differ widely as to the degree in which this appearance of a lateral succession of pairs finds expression. Toward the genal angles, the pits of these first two rows become alternate. The pits on the lower surface of the cephalon correspond in position to those on the upper surface, and between the first and second rows on this lower surface, there is a raised ridge which may be traced backward into the genal spines. In well preserved specimens the latter extend straight backward, continuing in the direction of the lateral border of the cephalon. Specimens differ greatly in their relative width and length, probably due to different degrees of depression of the convex cephalon, but the best preserved specimens show a ratio of 44 per cent between the length of the cephalon, as far back as its straight posterior border, and its width.

The specimens here described were obtained from a block in the upper part of the Gulf west of Turin, near the upper part of the road ascending southwestward toward a school house on the pike. Here it lay with other similar rocks along the side of the road, as if thrown out of a ditch while repairing the road. The same block contained a flat form of *Zygospira*, somewhat resembling some of the smaller specimens referred to *Zygospira cincin-*

natiensis, Rafinesquina alternata, Cyrtolites ornatus, Liospira vitruvia, Protowarthia cancellata, Cymatonota pholadis, Byssonychia radiata, Calymene, and several new species of gasteropoda. The horizon is regarded as below that at Pulaski, but how far is not known. The *Zygospira* above mentioned is the one figured by Hall, in the *Paleontology of New York,* vol. I (plate 79, Fig. 6), probably from Turin, as *Atrypa increbescens.*

With these specimens described from the block found in the upper part of the Gulf, west of Turin, the forms of *Trinucleus concentricus* found in the *Rafinesquina nasuta* block, west of the railroad bridge, a mile east of Pulaski, and those found in situ at Pulaski, Lorraine, and numerous other localities in the middle Lorraine, appear to agree perfectly, but better specimens are needed for final determination.

50. **Calymene conradi,** Emmons

The following description of *Calymene conradi* was published by Emmons in his *American Geology,* p. 236, in 1856:

> Small, wide across the cheeks; cheek angles obtuse or rounded; posterior lobes of the glabella comparatively large and globular; thoracic lobes very convex, with a row of tubercles in the furrow or between the axis and the lateral lobes. Lorraine shales.

The fact that this species was described nine years after the publication of vol. I, of the *Paleontology of New York* suggests that Emmons, in his description was trying to distinguish the Lorraine form from the published figures and description of *Calymene senaria* as given by Hall. If so, it will be necessary to establish the species upon other grounds than those cited, although it is practically certain that the Lorraine form of New York is specifically distinct from the *Calymene senaria,* typically found in the Trenton limestone of that state.

51. **Proetus chambliensis,** sp. nov.

(Plate IV, Figs. 1A–H)

The specimens here described (No. 8435, in Victoria Museum) lie flattened in a small rock fragment collected on the Richelieu River, at Chambly, Quebec, a short distance west of the dam.

Surface practically smooth under an ordinary lens. In one

specimen the length is 14.5 mm. The length of the cephalon along the median line is nearly 5 mm. The length of the thorax is 5.5 mm. The length of the pygidium, 4 mm. The length of the head to a line connecting the tips of the genal spines is 7.5 mm.

The width of the head between the tips of the genal spines slightly exceeds 10 mm. The width of the anterior part of the thorax is about 9 mm. For about 6 segments, the width of the thorax remains about the same, but it becomes narrower posteriorly. The width of the pygidium is about 6 mm.

The width of the posterior part of the glabella is about 3.5 mm. The length of the glabella, as far as the nuchal groove, is 3 mm. As in other species of *Proetus*, the glabella is slightly enlarged posteriorly, where it adjoins the concave curvature of the large palpebral lobes. A short, faint groove, scarcely 1 mm. in length, starts opposite the middle of the palpebral lobe and extends diagonally backward, limiting the anterior part of the posterior pair of lateral lobes of the glabella. A second, fainter groove extends diagonally inward and moderately backward from about the anterior edge of the raised rim of the palpebral lobe. The distance from a line connecting the lateral terminations of this second pair of grooves as far as the anterior edge of the glabella is 1 mm. A third, still shorter and fainter pair of grooves is found anterior to the second pair and is scarcely visible.

The facial suture starts slightly exterior to a point directly in front of the palpebral lobe, curves diagonally inward, apparently follows the outer edge of the lobe just below the visual surface, and posteriorly bends outward again at an angle of about 45 degrees with a directly transverse line, cutting the posterior margin of the cephalon within 1.5 mm. of the longitudinal furrow limiting the axial lobe of the thorax, and an equal distance from the groove limiting the inner edge of the border of the cephalon at the genal angle. The visual surface is smooth and has a lunate form.

At the genal angle, the marginal border of the free cheek has a width of about four-fifths of a millimeter. The length of the genal spine is 2.5 mm., in the case of the specimen here described, but in a larger specimen on the same rock fragment, it equals 3.5 mm.

Anteriorly, the glabella is distinctly defined, and is separated from the marginal border of the cephalon by a narrow space about

equalling the width of the border, the two together equalling about four-fifths of a millimeter.

The axial lobe of the thorax has a width of fully 3.5 mm., narrowing to 2.5 mm. at the anterior end of the pygidium.

The number of pleural segments is ten. A median groove follows the lateral lobes of these segments laterally to the point where they curve posteriorly. The length of this posteriorly directed part is approximately between 1 and 1.5 mm.

Axial lobe of pygidium distinctly defined posteriorly as well as laterally. Its length is 2.8 mm. in a pygidium whose length is 3.8 mm., the flattened marginal border of the pygidium having a width of 1 mm. Essentially the same width of border is shown posteriorly by pygidia which have a length of nearly 5 mm.

The anterior annulation of the axial lobe of the pygidium, which is in contact with the thorax, is relatively narrow but strongly defined. The second annulation is the first one fully exposed, and is always very distinct. It is followed by one fairly distinct annulation, three much less distinct annulations, and rarely by another scarcely perceptible annulation, the last being followed by a space having room for two more annulations, where, however, none are present.

On the lateral lobes of the pygidium, the anterior pleural segment, adjoining the pleural segments of the thorax is strongly marked posteriorly. The next pleural segment is the first one fully exposed; this is fairly distinct, and has an indication of a median groove. This is followed by two much less distinct indications of pleural segments with no trace of a median groove, followed by another, scarcely perceptible pleural segment. The first fully exposed pleural segment extends across the flattened border of the pygidium. The remainder scarcely affect the border. The flattened border of the pygidium is relatively broad and slightly concave.

The specimens here described were obtained at Chambly Canton, on the southern side of the Richelieu River, a short distance below the dam. It occurs also at several localities east of Ottawa, among these: about a mile northwest of Hawthorne station; also along the road reached by going three quarters of a mile west of Vars, along the railroad, and then from half a mile to a little more than a mile northwestward along the public road. Along the Nicolet River, southwest of Ste. Monique, *Proetus* ranges from

533 to 1002 feet below the lowest horizon containing *Strophomena planumbona* and *Rhynchotrema perlamellosa.*

At the locality at the cross roads found by going three-quarters of a mile west of Vars, along the railroad, and then more than a mile northwestward, *Proetus chambliensis* is found associated with the following fossils: columnals usually referred to *Glyptocrinus, Dalmanella, Rafinesquina mucronata, Plectambonites, Zygospira modesta, Pholidops subtruncata, Byssonychia radiata, Clidophorus* resembling *praevolutus, Cymatonota pholadis, Cuneamya scaphabrevior, Lyrodesma poststriatum, Psilonychia inornata, Rhytimya* belonging to *oehana* group, *Eotomaria, Bythocypris cylindrica, Ctenobolbina* resembling *ciliata, Acidaspis,* and *Calymene.*

Along the same country road, west of Vars, but scarcely half a mile north of the railroad, *Proetus chambliensis* occurs associated with: columnals usually referred to *Glyptocrinus, Rafinesquina mucronata, Plectambonites, Pholidops subtruncata, Clidophorus* resembling *praevolutus,* and *Pterinea demissa.* The loose blocks in the neighboring fields, probably from various horizons, including even Richmond boulders, contained the following additional species: *Hebertella occidentalis, Strophomena sulcata, Zygospira modesta, Catazyga headi,* and *Clathrospira* closely resembling *subconica.*

Along the railroad, a mile northwest of Hawthorne station, *Proetus chambliensis* occurs associated with the following species: columnals usually referred to *Glyptocrinus, Pholidops subtruncatus, Dalmanella, Plectambonites, Rafinesquina mucronata, Hebertella occidentalis, Zygospira modesta, Lyrodesma poststriatum, Pterinea demissa, Ctenodonta lorrainensis, Cornulites, Bythocypris cylindrica,* and *Calymene.* In addition to these, loose blocks contain *Catazyga headi, Byssonychia radiata,* and *Isotelus.*

The exposures between Ottawa and Vars include representatives chiefly of this *Proetus* zone, with one exposure containing Richmond fossils, and one containing *Triarthrus,* and belonging near the base of the Lorraine. There is no trace of the *Leptaena* zones belonging between the *Proetus* and *Triarthrus* zones, as exposed along the Nicolet River. While it is very probable that the Lorraine section thins westward from the Nicolet River toward Ottawa, it also is probable that a considerable part of the failure of missing zones to appear in the Ottawa area is due to faulting.

Proetus parviusculus, Hall, was described from Cincinnati,

Ohio. There it is listed by John M. Nickles from the Corryville horizon. The glabella is rotund oval, without visible lobation. The border of the cephalon is broad and flat, even anteriorly, and defined from the remainder of the cephalon by its more nearly horizontal slope as well as by the shallow groove; there is no additional narrow elevation along the margin of the border. Thoracic segments comparatively prominent. Pygidium with prominent axis, and flat lateral lobes having a plain expanded border; lateral lobes with about four indicated segments, becoming indistinct posteriorly, the first two with longitudinal furrows. In *Proetus chambliensis* the glabella is relatively longer and more oblong oval in outline. It presents not only fairly distinct indications of the large basal lobes, but also indications of the middle pair, the limiting furrows being readily distinguishable under a lens. Along the outer margin of the flat border of the cephalon there is a very narrow elevated line, which becomes broader and more prominent just before reaching the anterior part of the facial suture, and which gives rise to the strongly defined marginal elevation of the cephalon at the edge of the border anterior to the glabella. The eyes are relatively longer and more closely appressed to the glabella. The thoracic segments are less prominent, especially along the axial lobe. The axial lobe of the pygidium rises strongly above the very moderately convex lateral lobes, and only the anterior segments are distinctly indicated. While unquestionably closely related to *Proetus parvusculus*, it seems possible to distinguish the Canadian forms for the reasons indicated.

52. **Byssonychia carinata,** Goldfuss

(*Petrefacta Germaniae, vol. II, p. 136, pl. 119, Fig. 8.*)

From the single figure accompanying this description it is evident that the form is a species of *Byssonychia*. Twenty-two plications are indicated between the posterior margin and the abrupt descent of the umbonal ridge at the anterior face; possibly 5 more plications belong to the anterior face, making a total of 27 plications, as figured. The original specimen may have had more, especially toward the posterior margin of the hinge-line. The general outline of the shell is not rotund but obliquely quadrate oblong with the greater axis in an approximately vertical

direction, somewhat as in *Byssonychia praecursa*, Ulrich, described from the Lorraine shales of Lorraine, New York. The original description states that, anteriorly, the shell is strongly arched or convex, and steeply or abruptly cut off. This type of structure occurs in *Byssonychia praecursa* and *B. richmondensis*. In the figure presented by Goldfuss, the abruptness and flattening of the anterior face is not strongly indicated, but is suggested by the considerable width of the anterior face, both valves being present in the individual figured.

The following description was presented by Goldfuss:

Pterinea testa ovata ventricosa obliqua antice abrupta postice declivi, margine cardinali brevi, ala postica truncata, costis radiantibus regularibus convexis, interstitiis latioribus plano-concavis.

Occurit in Psammite Americae septemtrionalis et Provinciae montanae. M. B.

Steinkerne dieser Art kommen bei Lewistown in Oneida-County und im Bergischen in der Grauwacke vor. Sie sind eyfoermig, vorn hochgewoelbt und steil abgeschnitten, nach hinten abschluessig, in den kurzen stumpf winkeligen Fluegel uebergehend. Die kurze Schlosslienie macht der Achse einen spitzigen Winkel, und vom Winkel strahlen starke, convexe Rippen aus, welche nach hinten allmaelig schmaeler werden. Ihre Zwischenraeume sind eben so breit und flach-concav. Bei einem Exemplare sieht man vor dem Wirbel leistenfoermige Zaehne, und bei einem andern sind Spuren zahlreicher concentrischer Streifen bemerklich.

The figure published by Goldfuss leaves no doubt of the distinctness of *Byssonychia carinata* from *Byssonychia radiata*. The description and the figure together indicate a species of the *Byssonychia praecursa* and *Byssonychia richmondensis* type. Considering the fact that the former species was described from the Lorraine of New York and that the latter is a Richmond form, the presumptive evidence might be considered at first as in favor of *Byssonychia praecursa*. According to Ulrich, the number of radiating plications in *Byssonychia praecursa* varies from 38 to 42, while those of *Bysonychia richmondensis* number not less than 50. It is practically certain that the number of plications indicated by the figure of *Byssonychia carinata* published by Goldfuss is too small. In *Byssonychia praecursa* the anterior face is not as strongly flattened and the beak is more rounded than in *Eyssonychia richmondensis*. These also are features apparently indicated by the figure of *B. carinata*. As regards the locality

cited by Goldfuss, Lewistown, in Oneida-Country, this probably should read Lewistown, Ontario Lake. In that event, it may be worth while noting that forms resembling *Byssonychia richmondensis* occur in the Richmond north of Lake Ontario, as far east as Streetsville, a short distance west of Toronto.

The specimen figured by Hall (*Paleontology of New York, vol. I, pl. 80, Figs. 5a, 5b*) is stated by Whitfield and Hovey to have been found loose on the south side of Lake Ontario. It gives indications of the presence of 30 plications, and formerly must have had at least 2 more, the full number not being known. Another specimen, not figured, but preserved in the Hall collection in the American Museum of Natural History, and evidently collected after the publication of vol. I, presents the outline and the broad, flat anterior face of *Byssonychia richmondensis*, and almost certainly belongs to that species. The anterior umbonal angle is abrupt. The number of plications preserved is 33, and the original number must have equalled 37. It is regarded as belonging to the same species as the form figured by Hall.

The result of these studies has been to definitely determine that *Byssonychia carinata*, of Goldfuss, belongs to the group of species having a flattened anterior face, but an actual examination of the type must be made to definitely determine the identity or nonidentity of this species with *Byssonychia praecursa* or *B. richmondensis*. Under these circumstances, it seems best to discard the use of Goldfuss's name, until more is known regarding his type.

A Taeniaster from the Richmond of Meaford, Ontario

Taeniaster meafordensis, sp. nov.

(Plate IV, Figs. 5, 6, 7)

Central disc 7 to 8 mm. in diameter. Rays 11 to 15 mm. in length. Total spread of the animal, including the rays, therefore about 35 mm. Rays 2 mm. wide at the margin of the central disc, tapering rather gradually toward the extremities.

Ambulacral groove occupied by two rows of ambulacral plates, about 8 in a length of 5 mm. Those on opposite sides of the median line alternate with each other, the adjoining margins being slightly concave, so that two adjoining ends on one side of the median line fit against the concave middle of the plate on the

other side. The lateral distal quarter of the ambulacral plate area is strongly depressed as though for the passage of the tube feet. This gives the ambulacral plates on the right side the appearance of a short stumpy L, while those on the left side have the same appearance with the direction of the foot of the L inverted. This feature is well exhibited along that part of the ray traversing the central disc, and along half the length of the free part of the ray. Farther out, the ambulacral plates become more narrow and the L form is less in evidence.

Laterally, the ambulacral plates are bordered by the adumbulacral plates. Each ambulacral plate begins at the extremity of the base of L-like ambulacral plate and extends beyond the base of the next distal plate, successive adambulacral plates overlapping like a series of tiles, concave on the inner side and convex outside. A single narrow rotund spine is attached to each adumbulacral plate, the point of attachment being near the distal margin of the plate somewhere near its median axis. If any other plates are present on the ventral side, these have not been detected. Moreover, the presence of actual passages for the tube feet has not been seen, though inferred from the visible part of the ambulacral plates.

On the dorsal side, the rays are strongly convex. There are two rows of ossicles, the two rows alternating. These ossicles are transversely convex, and adjoin laterally a series of distally overlapping plates which are assumed to be the adumbulacral plates already described; toward their distal margins each of these adumbulacral plates bears a single rotund spine about as long as the supporting plate itself.

The entire dorsal surface of the rays and of the central disc appears to have been covered with a thin integument which was minutely granular. Some of these granules are larger and may have supported minute spines or other appendages. Minute spines probably were numerous also on the interambulacral parts on the ventral side of the disc, but in the present state of preservation of the specimens, the presence of these spines can not be determined definitely.

Only 5 oral ossicles can be detected, one at each interambulacral angle; however, since they extend distally like the sides of the letter V into the adambulacral rows of plates, it may be assumed that they are homologous to the 5 pairs of plates found in typical

Taeniaster. At their proximal terminations these oral ossicles are blunt and strongly elevated.

Only the more conspicuous elements of structure can be detected in the specimens at hand. Therefore there is opportunity for glaring misinterpretations of structure on the part of the present writer.

Locality. About 220 feet above Lake Huron, on Workman's creek, three miles southeast of Meaford, Canada, in the Richmond group.

Compared with *Taeniaster elegans*, Miller, from the Waynesville member of the Richmond, in Ohio, the adumbulacral plates are longer, distinctly overlapping, and bear correspondingly shorter spines; the oral ossicles are more blunt and more conspicuously elevated at their proximal terminations; nevertheless it is with this species that the Meaford form is most closely related.

Taeniaster miamiensis, Miller, from the Waynesville member in Ohio, is figured as having more strongly overlapping adumbulacral plates, with shorter spines, two being figured to a plate; the L-shaped form of the ambulacral plates is not indicated although it probably was present; the oral ossicles are figured as longer and with less divergent posterior terminations.

It is evident that both *Taeniaster elegans* and *Taeniaster miamiensis* must be republished before these species can be made available for purposes of correlating other forms believed to belong to approximately the same stratigraphical horizons. The types of both forms are now in the possession of the U. S. National Museum, but were in the exhibition cases at the time of my visit, from which it was difficult to remove them within a short time owing to the heavy plate glass front. Under these circumstances the examination of the specimens proved not sufficiently illuminating. While the Meaford specimens are regarded as indicating the Waynesville age of the strata in question, the actual identity of these specimens with *Taeniaster elegans* or *Taeniaster miamiensis* could not be demonstrated.

EXPLANATION OF PLATES

PLATE I

Fig. 1. Whitella securiformis. Riviere des Hurons, province of Quebec. Type. Geological Survey of Canada.

Fig. 2. Whitella complanata. Riviere des Hurons, province of Quebec. Type. Geological Survey of Canada.

Fig. 3. Whitella goniumbonata. Riviere des Hurons, province of Quebec. Geological Survey of Canada.

Fig. 4. Modiolopsis postplicata. Riviere des Hurons, province of Quebec. Geological Survey of Canada.

Fig. 5. Orthodesma approximatum. Chambly village, province of Quebec. Geological Survey of Canada.

Fig. 6. Clidophorus praevolutus. Two specimens, not types. Riviere des Hurons. Geological Survey of Canada.

Fig. 7. Modiolodon poststriatus. One mile west of Vars, province of Quebec. Geological Survey of Canada.

Fig. 8. Pholadomorpha chambliensis. Chambly village, province of Quebec. Geological Survey of Canada, No. 2069.

Fig. 9. Cymatonota lenior. Riviere des Hurons, province of Quebec. Geological Survey of Canada.

Fig. 10. Caritodens demissa, Conrad. Riviere des Hurons, province of Quebec The terminations of the anterior ear and posterior wing are omitted. Geological Survey of Canada.

Fig. 11. Rhytimya oehana, Ulrich. Chambly village, province of Quebec. Geological Survey of Canada.

Fig. 12. Clidophorus praevolutus. Chambly village, province of Quebec. Geological Survey of Canada, No. 2079.

Fig. 13. Clidophorus sp. Rome, New York. From collections of the New York State Museum at Albany, No. R–1232.

Fig. 14. Cymatonota pholadis, Hall. Chambly village, province of Quebec. Geological Survey of Canada.

Fig. 15. Orthodesma prolatum. Beach below Becanceur river, province of Quebec. Geological Survey of Canada, No. 2144.

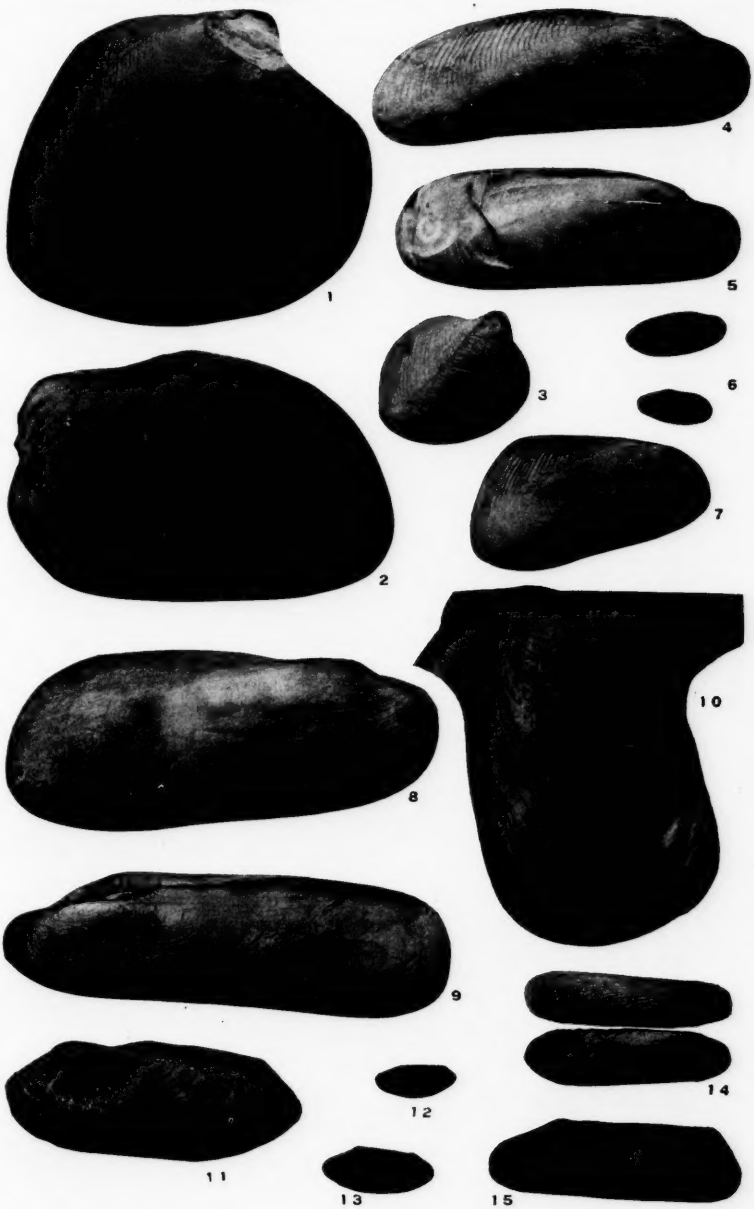
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PLATE II

Fig. 1. Pterotheca pentagona. Chambly village, province of Quebec. Geological Survey of Canada, No. 2155.

Fig. 2. Pterotheca pentagona. Nicolet River, southwest of Ste. Monique, province of Quebec. Geological Survey of Canada.

Fig. 3. Pterotheca cf. attenuata, Hall. Western shore of Cloche peninsula, province of Ontario. Geological Survey of Canada. Lower Lowville red clay shales.

Fig. 4. Strophomena planumbona, variety. *A*, Chambly village, No. 8404. *B*, Riviere des Hurons, No. 8405. Both from the province of Quebec. Geological Survey of Canada.

Fig. 5. Archinacella clochensis. Western shore of Cloche peninsula, province of Ontario. Geological Survey of Canada. Lower Lowville red clay shales.

Fig. 6. Cyrtodonta clochensis. Western shore of Cloche peninsula, province of Ontario. Geological Survey of Canada. Lower Lowville red clay shales.

Fig. 7. Rafinesquina mucronata. A mile northwest of Vars, province of Quebec Not the types. 7 A, No. 8432; 7 B, No. 8432 a; Victoria Memorial Museum, Ottawa, Canada.

Fig. 8. Lophospira beatrice. Riviere des Hurons, province of Quebec. Types. Geological Survey of Canada.

Fig. 9. Psiloconcha borealis. *A*, *B*, Riviere des Hurons; *C*, Nicolet River, southwest of Ste. Monique; all from province of Quebec. *B* is selected as type. Geological Survey of Canada. *A*, No. 2087. *B*, No. 8411. *C*, No. 8412.

Fig. 10. Colpomya pusilla. Chambly village, province of Quebec. Not the type.

Fig. 11. Lingula clochensis. *A*, pedicel valve, No. 8403; *B*, brachial valve, No. 8403*a*. Western margin of Cloche peninsula, province of Ontario. Geological Survey of Canada. Lower Lowville red clay shales.

Fig. 12. Cuneamya brevior. Riviere des Hurons, province of Quebec. Geological Survey of Canada.

Fig. 13. Technophorus quincuncialis. Chambly village, province of Quebec. Geological Survey of Canada.

Fig. 14. Pholadomorpha divaricata. Riviere des Hurons, province of Quebec. Geological Survey of Canada, No. 2071.

Fig. 15. Psiloconcha subovalis, Ulrich. Riviere des Hurons, province of Quebec. Geological Survey of Canada.

Fig. 16. Pholadomorpha pholadiformis, Hall. Two miles northeast of Gore Bay, along the shore, Manitoulin island, province of Ontario. Geological Survey of Canada.

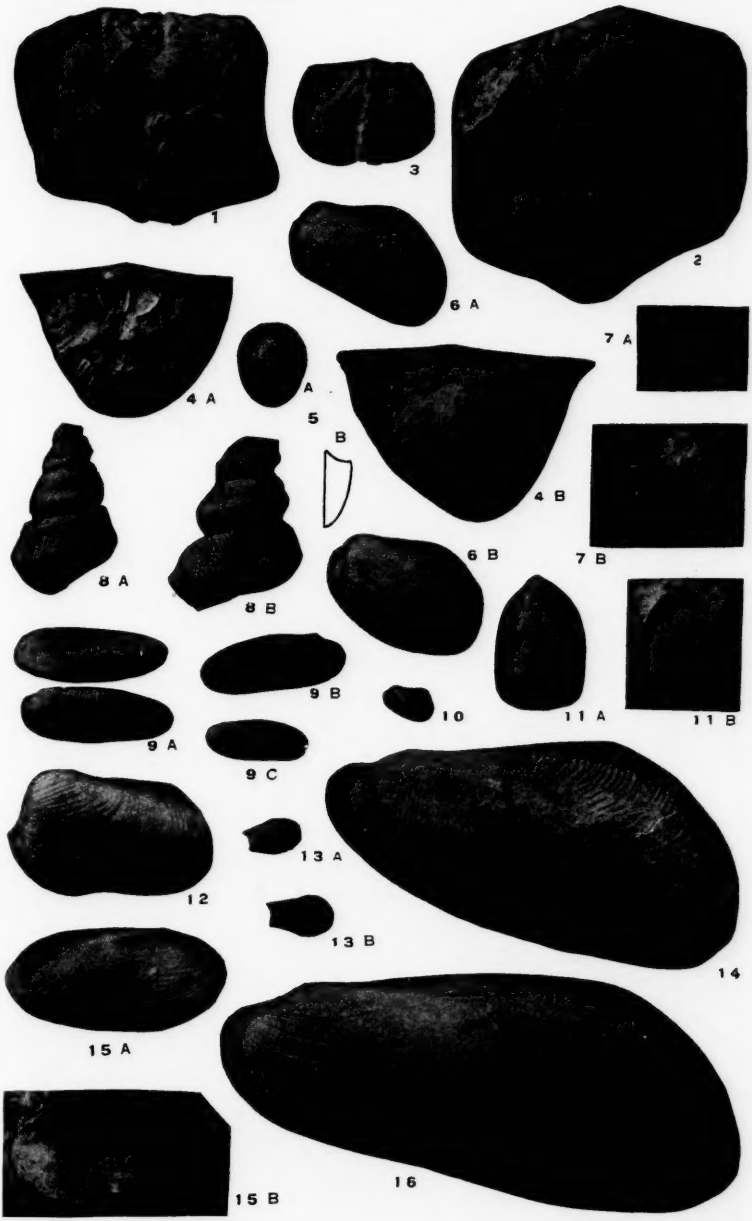

1
3
2
6 A
7 A
4 A
A
5
B
4 B
6 B
7 B
8 A
8 B
9 B
9 A
10
11 A
11 B
9 C
12
13 A
13 B
14
15 A
15 B
16

PLATE III

Fig. 1. Modiolopsis modiolaris, Hall. Half a mile east of Worthville, New York, along a creek north of the pike.

Fig. 2. Rafinesquina nasuta, Conrad. Pedicel valves. From a ferruginous boulder containing *Trinucleus*, a short distance west of the railroad bridge, a mile east of Pulaski, New York.

Fig. 3. Archinacella pulaskiensis. Pulaski, New York, west of the railroad bridge, one mile east of New York.

Fig. 4. Colpomya pusilla. In *Trinucleus* bed, west of railroad bridge, one mile east of Pulaski, New York.

Fig. 5. Orthodesma nasutum, Conrad. Two and a half miles east of Worthville, New York.

Fig. 6. Orthodesma pulaskiensis. Immediately below railroad bridge, one mile east of Pulaski, New York.

Fig. 7. Cymatonota pholadis, Conrad. Near head of Gulf west of Turin, New York, along road leading southwest up the hill toward a school house.

Fig. 8. Ctenodonta lorrainensis. Half way between Lorraine and Worthville, New York, where the pike crosses a creek. *A*, interior cast; *B*, interior cast of the opposite valve, inverted, with beak down.

Fig. 9. Glyptorthis crispata, Emmons. Half way between Lorraine and Worthville, New York, where the pike crosses a creek.

Fig. 10. Orthodesma sp. At the cross roads one mile south of Barnes Corners, New York. See under *Orthodesma pulaskiensis*.

Fig. 11. Pterinea (Caritodens) demissa, Conrad. Young specimen. Chambly village, on the Richelieu river, Province of Quebec. Geological Survey of Canada. No. 8433, Victoria Memorial Museum, Ottawa. Canada.

Fig. 12. Byssonychia radiata, Hall. *A*, Form with 55 plications; *B*, with 47 plications. *C*, with 48 plications; type of species, the original of Fig. 4*a*, on plate 80, vol. I, *Paleontology of New York*. Pulaski, New York.

Fig. 13. Lingula sp. Belonging to the *Lingula procteri* group. At the *Trinucleus* horizon, a short distance west of the railroad bridge, one mile east of Pulaski, New York. See under *Lingula rectilateralis*, Emmons.

Fig. 14. Ischyrodonta *curta*, Conrad. Bennett Bridge, one mile down stream from Salmon River Falls, New York.

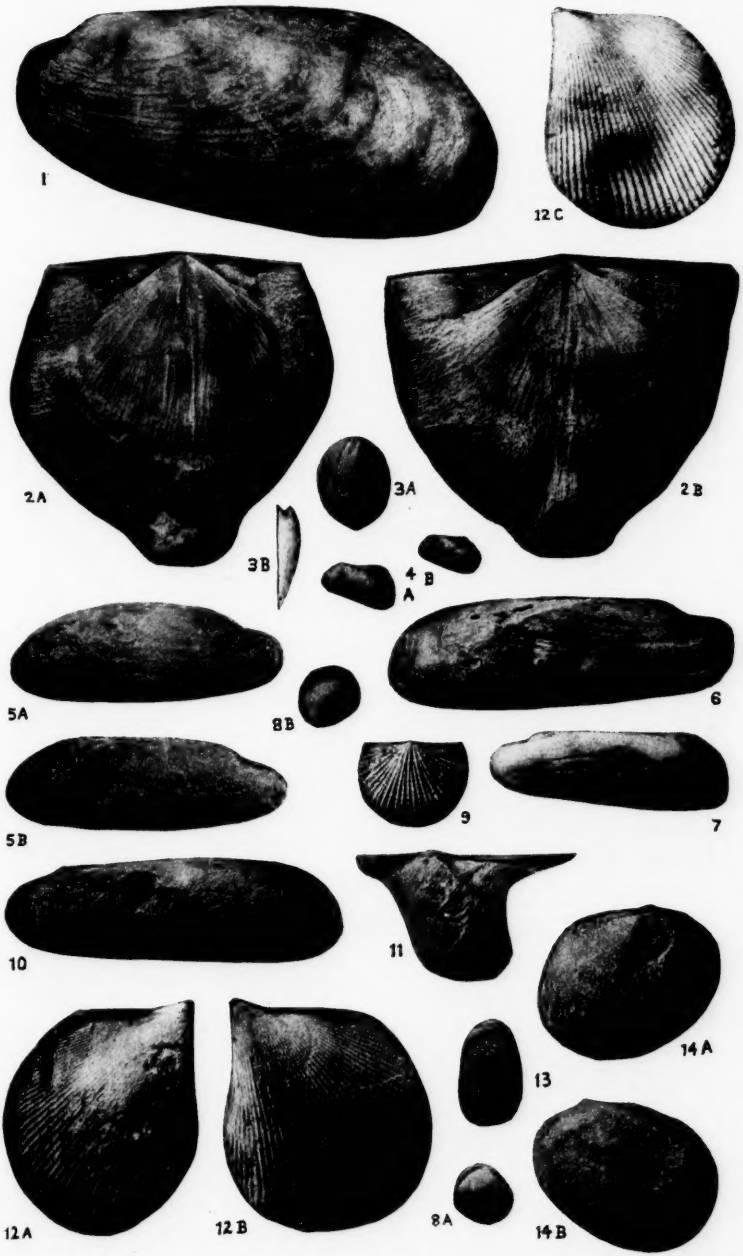

1
12C
2A
3A
2B
3B
4B
A
5A
8B
6
5B
9
7
10
11
14A
13
12A
12B
8A
14B

PLATE IV

Fig. 1. Proetus chambliensis. *A*, *B*, *C*, complete individuals, the latter partially exposed, exhibiting the genal spines; the glabella is best preserved in *A*. The neck ring is best seen in *D*, and *E*. The pygidium is well shown by *E*, *F*, *G*, and *H*. The curvature of the extremities of the pleural segments best seen in *G*. Rock fragment collected at Chambly village, a short distance south of the dam across the Richelieu River, in the province of Quebec. Preserved in the Victoria Memorial Museum, Ottawa, Canada, No. 8435. Figure magnified two diameters.

Fig. 2. C. Rafinesquina nasuta, Conrad. Cast of interior of pedicel valve, from large rock containing Trinucleus, Modiolopsis modiolaris, and numerous other Lorraine fossils, a short distance west of the railroad bridge at Pulaski, New York.

Fig. 3. Archinacella pulaskiensis. *C*, View from above. *D*, a lateral view. From the Trinucleus horizon several hundred yards west of the railroad bridge, at Pulaski, New York.

Fig. 4. Pasceolus globosus, Billings. Specimen showing concave plates with radiating grooves. A short distance below the Fulton layer, in the Point Pleasant limestone section, at the quarry west of Point Pleasant, Ohio.

Fig. 5. Taeniaster meafordensis. *A*, *B*, two specimens showing the oral side. *C*, specimen showing the aboral side; only the lower arm in the left side, as figured, is well exposed.

Fig. 6. Taeniaster meafordensis. *D*, oral side, poorly preserved. *E*, *F*, aboral side, with the surface of one of the arms, in *F*, well exposed.

Fig. 7. Taeniaster meafordensis. *G*, a specimen with the arms bent back. Specimens in this attitude were common in the rocks layer from which the various fragments here illustrated were obtained. Hundreds of individuals were crowded closely together. Richmond group, along Workman creek, three miles southeast of Meaford, Ontario, Canada.

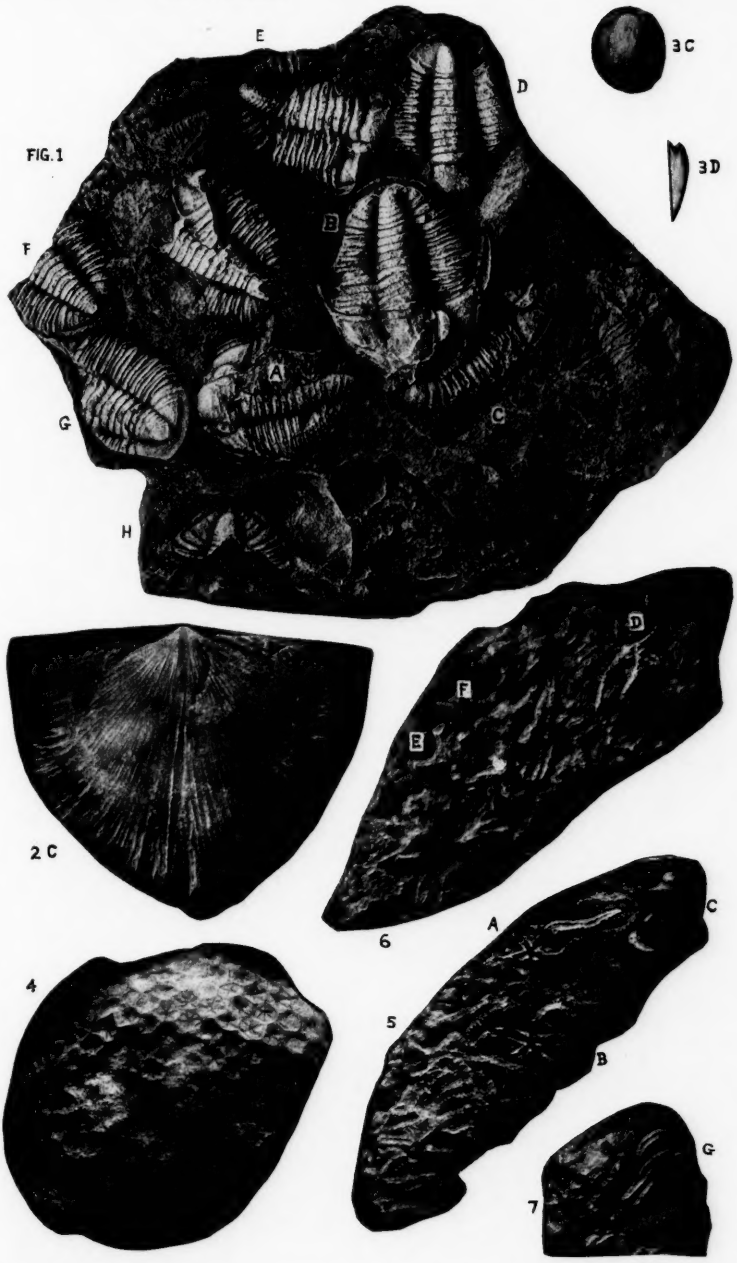


FIG. 1
E
D
B
F
A
G
C
H
3C
3D
2C
D
F
E
6
A
C
4
5
B
G
7

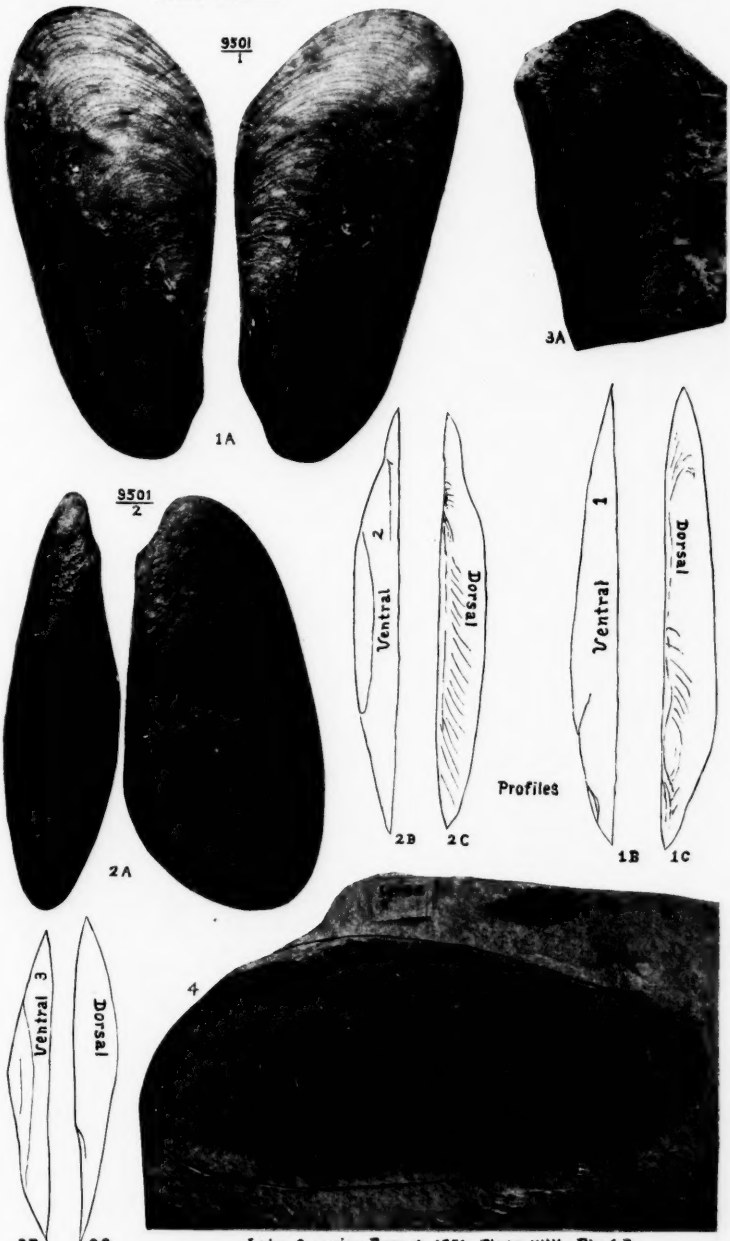
PLATE V

Fig. 1. Modiolopsis modiolaris, Hall. *A*, two valves, as seen on a single slab; original of Fig. 1*a*, on plate 81, *Paleontology of New York*, vol. I; preserved in the New York State Museum at Albany, New York, as No. 9501–1. In a sandy, somewhat micaceous shale at Rome, New York. *B*, *C*, ventral and dorsal profiles, prepared by Dr. Ruedemann, but not intended for publication.

Fig. 2. Modiolopsis modiolaris, Hall. *A*, two valves, as seen on a single slab; original of Fig. 1*b*, on plate 81, *Paleontology of New York*, vol. I; No. 9501–2 in New York State Museum. In a gray sandstone from Rome, New York. *B*, *C*, ventral and dorsal profiles, sketched by Dr. Ruedemann.

Fig. 3. Orthodesma nasutum, Conrad. *A*, left valve, injured along the upper margin anterior to the beak; outline here incorrect; original of Fig. 2, plate 81, *N. Y. Pal.* I; No. 9600–1, in N. Y. State Museum. Labeled as coming from Lorraine, Jefferson county, New York. *B*, *C*, ventral and dorsal profiles, sketched by Dr. Ruedemann.

Fig. 4. Pholadomorpha pholadiformis, Hall. Original of Fig. 1*b*, on plate XXX, accompanying the original description in Report on the Geology of the Lake Superior Land District, by Foster and Whitney, in 1851. In type series 1365, preserved in the American Museum of Natural History, in New York city. Specimen poorly preserved. Outline, as interpreted by the writer, indicated in ink. The elevation above the anterior muscular scar is the beak, near which the specimen is injured by crushing.



Lake Superior Report, 1851, Plate XXX, Fig. 1 B.

A COMPARATIVE STUDY OF CIRCULAR AND RECTANGULAR IMHOFF TANKS[1]

THEODORE SEDGWICK JOHNSON

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INTRODUCTION

No other development of sanitary engineering has taken place that has aroused so much interest as the Imhoff, two-story sedimentation tank. Installed first in the Emscher district in Ger-

[1] Thesis presented to Ohio State University for degree of C.E., June, 1913.

many in 1906, its use in America is comparatively new, there probably being to date no more than one score of installations. Experiments at Philadelphia and Chicago have proved favorable, and at least one large city—Atlanta, Georgia—has installed them as adjuncts to disposal plants.

This thesis attempts an economic design of two such tanks as applied to the disposal plant of a small community, and makes comparisons of rectangular and circular tank, with special regard to costs and clarification efficiency.

Historical Sketch of Development of Clarification Methods

At this point a brief digression into the history of the Imhoff tank may be of value.

In 1810 the water-closet was reinvented and its use in the cities of the Continent and in England rapidly increased. Until 1815 the drains of London, as they were called, were not intended to carry any but surface wastes, and it was not until that time that the members of English communities realized the need of sanitary precautions and ordered all water-closets to be connected to the drains or sewers, as they really began to be.

This led, of course, in the thickly populated districts of Europe, to a fearful state of river pollution, which continued until 1858 in England, when, as a result of a Sanitary Commission's report, further pollution of the rivers was prevented. In Germany the same conditions were generally true, finding their worst condition in the Emscher district. This district was placed under the control of the Emschergenossenschaft in 1906, though steps had been taken to improve the wretched sanitary conditions of the valley as early as 1889.

When river dilution was prohibited, various stages of disposal processes were gone through, tending chiefly in the direction of purification by infiltration. In any of the early disposal processes, serious trouble was caused by the suspended solid material, partly material and partly organic in nature. To remove this suspended matter, various types of sedimentation processes were resorted to. Sedimentation may be either plain or chemical, and both types may be further classified as grit chambers and true sedimentation tanks. Again, the latter may be re-classi-

fied, according to the manner of disposal of the sludge or settled solid matter. If the sludge remains in the bottom of the tanks until partly liquiefied by bacterial action, the tank becomes a septic tank.

H. W. Clark, at the Lawrence Experiment Station, under the direction of the Massachusetts State Board of Health, in 1899 suggested the idea of a separate compartment for the settled out portions into which they could be occasionally flushed for further digestion and bacterial action, and in accordance with this idea a tank was constructed in November, 1899.

In England, Dr. W. O. Travis and his assistants, acting upon the favorable results of the Lawrence experiments, developed a type of hydrolytic or septic tank, which they patented and began to use in service in 1903. The improvement over the Lawrence idea lies in the fact that both compartments are parts of the same tank.

In the work of the Emschergenossenschaft, under the direction of Dr. Karl Imhoff and Mr. Chas. Saville, the Travis hydrolytic tank was experimented on, beginning in 1906, and modifications were soon made, which had for their specific purpose the prevention of any disturbance of the settled out solids, by the sewage flow through the sedimentation chamber above. Continued experiments have been and are being made, looking toward the improvement of the tank treatment.

Briefly, the advantage of the tank lies in the stability of the clarified sewage, and the ease with which it can be subjected to later purification process; the freedom from objectionable odors; the absence of any dissolved oxygen in the digested sludge; the ease of manipulation and favorable character of the sludge, as compared with the sludge from the ordinary single story septic tank. The tank will be found to be more expensive to build, but gives evidences of operating results, which are worth the added expense.

The Imhoff tanks are built in three distinct types: (1) the radial flow tanks; (2) horizontal flow tanks, with rectangular digestion chambers, and (3) horizontal flow tanks, with circular digestion chambers. This thesis will discuss the comparative values of the first two types.

Data for Design

For the purpose of this thesis, the town of Granville, Licking County, is chosen, and the design is made as of one part of an entire sewer system and disposal plant.

Locality, Granville, Ohio. Granville is a small residence community, the seat of Denison University, and has a resident population of about 1300, which is increased to probably 2000 as a maximum during sessions of the University. The soil is of gravel and sand, characterized as glacial drift, and has been favorable for the long use of cess-pools.

The town is situated in the watershed of Raccoon Creek, a tributary to the Licking River, into which stream it empties at Newark, approximately seven miles away. The proximity of Newark, through part of which Raccoon Creek flows, together with the small flow of the stream at dry seasons, precludes the possibility of emptying untreated sewage directly into the stream.

Some method of purification will then be necessary. This thesis assumes the installation of a screen chamber, settling tank and intermittent sand filters, and will deal only with the settling tank, designing it, however, as a part of this particular disposal plant.

Tributary population. As stated above, the resident population is about 1300, and the present maximum about 2000. It will be some time after the introduction of the new system before this population will be tributary to the system. The town is not a manufacturing or industrial center, and, with the exception of the University, cannot be expected to have any great increase in population, and it would seem that at the end of five years a maximum population of 2500 and at the end of ten years a population of 3000 would be a generous estimate. The design will be based, therefore, on a population of 2500. Another factor that would make this figure a conservative one is the probability of important changes in methods of sewage disposal that may make changes necessary at a later time.

Character of sewage. The sewage will be that of a residence community, as almost no industrial wastes are produced in Granville. The sewer system is of the separate type, so no large amount of rainfall will reach the sewers. The sewers will be laid in gravel deposits, and in almost no case will the grade of

the invert be below ground-water level. This sewage, therefore, will be almost entirely domestic in composition, and will be very much diluted at first. Authorities differ in the amount of sewage per capita and the variations in it.

Amount of sewage. In the Emscher district the following values obtain: Recklinghausen has a daily flow of 83 gallons, Essen-North about 90, and two smaller towns 125 to 145 gallons per capita daily. Kinnicutt, Winslow and Pratt, in statistics of English towns, show values ranging from 35 to 95, and state that the average for English towns is 49.1 gallons per capita, for large towns about 100. In the Emscher District the maximum hourly flow is about one-eighteenth of the daily. Raikes says in English practice the minimum is one-half the average and the maximum twice the average.

Ogden says the maximum is 50 per cent more than the mean. He advocates also an indirect method, by finding the water consumption, taking 75 per cent of this for the average, and adding 100 per cent to the latter for a maximum. Fuller, in tables from Massachusetts State Board of Health report for Gardner, Massachhsetts, in 1898, and in reports for Columbus, shows that the maximum rate is about 125 per cent of the average.

For the purposes of this design, a flow of 75 gallons per capita daily and a maximum flow of one and one-half times the mean will be assumed.

This means, then, a flow of 2500×75 gallons or 187,500 gallons per day, or an average hourly flow of 7810 gallons. Assuming a maximum flow of one and one-half times the mean, we would have to provide for a maximum hourly flow of 11,715 gallons.

Detention period. After obtaining the quantity of sewage to be treated, the next factor in the design is the determination of the best period of detention or the flowing through time.

Opinion and practice differ in regard to what may properly be called solids capable of removal by sedimentation. The fundamental proposition of sedimentation is that every solid particle will settle in water at a velocity depending upon its size and weight and upon the viscosity of water. It is also found[2] to depend upon the area of the bottom surface exposed to receive

[2] Hazen's *Transactions of A. S. C. E.*, vol. liii, p. 45.

sediment. Travis used this idea by suspending many plates in the sedimentation basin.

A certain portion, therefore, of the solid content of sewage will settle to the bottom of the Imhoff tank in a relatively short time, while a larger portion will settle in three hours. After that, no appreciable increase in amount of sediment will take place, and the amount deposited at the end of six or eight hours will be little larger than that found at the end of three hours. Dr. Imhoff, in discussing this question, divides solids in sewage in four classes:

1. Settling solids, or those heavier portions which would settle out of still sewage in two hours' time.
2. Finely divided matter, or matter which would remain as residue after filtration through paper.
3. Colloidal matter, still finer, which would pass the filter paper but remain on a dialyzing membrane.
4. Matter that is in true solution.

It is only the solids in Class 1 that can be affected by the operation of plain sedimentation, though, of course, the length of time allowed—two hours—or the division line between classes one and two, might be uncertain. Dr. Imhoff claims, however that to rightly judge the efficiency of sedimentation processes, only the matter that comes under Class 1 should be included, as those capable of deposition. Any currents or velocity of flow in the tank would tend to decrease the amount of matter that would settle out of a given sewage, and efficiencies can therefore rightly be calculated on that basis. That means, then, that in Imhoff tanks a period of detention in excess of two hours is unnecessary. In existing plants the detention periods are as follows:

Plant	*Time*
Atlanta, Georgia	3 hours
Winters, California	3 hours
Philadelphia, Pennsylvania (experimental plant)	1 hour
Philadelphia, Pennsylvania (experimental plant) (deeper tank)	2 hours
Erie, Pennsylvania	40 mins.
Recklinghausen, Germany	1 hour
Essen-North	1 hour

From the character of the sewage to be treated in this installation, an average period of two hours will be assumed. For the

average flow, then, this means a capacity in the settling chamber of 15,620 gallons or a flowing-through time for maximum flow of $\frac{15,620}{11,715}$, or one hour and twenty minutes.

For a considerable period of time after the inception of the disposal process, it is probable that the period of detention will be much longer than the above figures.

In designing tanks, care must be taken to see that the flow is evenly distributed, that no "dead" places or places of low velocity occur.

In old-style, single-story, sedimentation tanks, the velocity was an important factor in design, as affecting the deposition of material. The effect of excessive velocity in the two-story tank is minimized by the fact that the solid part or sludge is removed from the disturbing effect of velocities on the liquid.

The velocities of flow in Imhoff tanks operated in the Emscher District have been studied, and Mr. Chas. Saville, formerly of the Emschergenossenschaft, recommends 0.20 of an inch per second, with 0.50 inch per second as a maximum, for satisfactory results.

Volume of sedimentation chamber. Knowing the value of average and maximum flows and the best detention period determines the volume or capacity of the settling chamber and the arrangement of baffles in the chamber will be such as to keep the velocity and mixing in proper condition.

Volume of sludge chamber. The next step in design is to determine the capacity of the sludge or digestion chamber.

The capacity of the sludge chamber will depend upon the character and amount of suspended matter. In the deeper tanks, the sludge, being under greater pressure, is much more compact than in the case of the shallow tank. The patentees of the tank recommend that the sludge chamber for shallow tanks be made 50 per cent greater than in the deep tank.

In large tanks some sludge may be drawn off every month, but in the smaller tanks the sludge should be kept nearly to the slots. Not all of the sludge should be removed at any one time. At the end of summer, the sludge is usually drawn off, to receive the winter's accumulation of sludge. The usual storage capacity is six months. In the plant at Winters, California, the sludge-chamber capacity was calculated on the basis of 0.007 cubic foot of sludge per capita per day.

Philadelphia experiments show 0.9 cubic yard per million gallon, or at a rate of 75 gallons per capita, a deposition of sludge at the rate of 0.002 cubic foot per capita per day.

Chicago experiments show 2 cubic yards during the summer and fall of 1910 and 0.93 cubic yards per 1,000,000 gallons for five months.

At Recklinghausen, 1.65 cubic yards, at Bochum, 2.1 and at Essen-N-W, 1.39. The last three values deal, of course, with strong sewage. Allen advises a sludge storage capacity to provide for a mean between the amount of fresh sludge and the final volume of treated Imhoff tank sludge. Allen states by formula the capacity $C = 5250\ PD$, where P is population, C capacity in cubic feet and D the day's retention of sludge.

Imhoff gives for Bochum (combined system) a value of 0.007 cubic foot per capita daily—the figure used in the Winters, California, installation, and says it would be half that much for separate system, or 0.0035. On these assumptions, John H. Gregory, for the Metropolitan Sewerage Commission of New York, prepared a table,[3] which gives for a daily sewage flow of 75 gallons per capita a volume of sludge of 1.7 cubic yards per 1,000,000 gallons.

Tabulating the various estimates:

	Cubic feet per capita daily
Winters, California	0.007
Philadelphia, Pennsylvania	0.002
Chicago, Illinois	0.002
Recklinghausen, Germany	0.0036
Bochum	0.0045
Essen, N-W	0.0031
Gregory (Metropolitan Sewage Commission)	0.0038
Pacific Flush Tank Company pamphlet	0.0033
Allen, Hazen (Amer. C. E.'s Pocket Book)	0.0022 to 0.0044

With these comparative figures before us, it seems reasonable to adopt a figure of 0.0035 cubic foot per capita daily, as the rate of deposition of sludge in the digestion chamber.

[3] Allen, *Sewage Sludge Treatment in the United States*, pp. 229.

Design of Tanks

Size of sedimentation and sludge chambers. 15,620 gallon capacity is equivalent to $\frac{15{,}620}{7.48} = 2085$ cubic feet (7.48 = the number of liquid gallons in 1 cubic foot). This is the required capacity of the sedimentation chamber.

For the assumed population of 2500 and a storage capacity for six months' sludge (required on account of winter storage of sludge) and a rate of 0.0035 cubic foot per capita per day, there will be required $2500 \times 0.0035 \times 6 \times 30 = 1575$ cubic feet, or 42 per cent of the total volume. With a storage capacity in the sedimentation chamber of 2610 cubic feet (calculated on the basis of two and one-half hours detention period) this would be 36.5 per cent of the total volume.

In view of the small size and necessary small depth of the tanks, this is the ratio of capacities of the sedimentation and sludge digestion chambers, though larger than usually specified, the ratio for the Proctor Creek plant in Atlanta, Georgia, being 25 per cent.

Stresses in tank walls. In calculating the stresses, for the purpose of detailed design, two kinds will develop.

When the tank is empty, earth pressure will act upon the walls inward, producing bending moments in one direction at the middle of one side of the rectangular tanks and in the opposite direction at the ends. In the circular tank compression will result in the entire ring.

As an alternative loading, the case may be considered where the tank is full of water, and because of slippage, earth contraction and bad construction, the backing has been removed far enough for flexure of the walls to take place, to develop flexural stresses of reverse signs in the rectangular tank and tensile stresses in the circular tank.

The sloping bottoms may be considered as any tank foundation and designed accordingly. At the points of connection with the vertical walls, stresses will be developed which are uncertain in amount and character, but will be provided for by connecting reinforcing steel.

The walls will be considered as slabs resting upon two vertical beams, and loaded uniformly along a horizontal strip. The two vertical beams may be either the end walls or intermediate beams

held apart at the top by a horizontal strut. The ends will be considered fixed and the same bending moment will be assumed at all corners. For a pressure P and width b and length l of the tank this negative bending moment will be found (by equating the moments from each side) to be $\frac{1}{2}p\ (b^2 - bl = l^2)$.

If the corners were hinges, the maximum bending moment would be $\frac{1}{8}pl^2$ in the center, but it is reduced by the negative bending moments produced by fixed ends. The value then becomes $\frac{1}{24}\ p\ (l^2 - 2\,bl - 2\,b^2)$ as the maximum on the side where l and b are the lengths of the sides. The pressure of the earth will be calculated from Rankine's formula

$$p = wh\,\frac{l + \sin\phi}{l - \sin\phi}$$ where $w = 100$ pounds cubic feet and $\phi = 30°$.

The pressure of the water will be determined by the usual hydrostatic law, $p = wh$. This would mean an earth pressure of 533 pounds per square foot and 998.4 pounds per square foot for water or total pressures on a vertical strip 1 foot wide of 3600 pounds and 6739.2 pounds.

If the long walls of the tank should be supported in the middle, the design would change to the condition of a continuous beam of two equal spans with fixed ends and consequent negative bending moments at each end and over the center support.

In this case, the maximum positive moment would be $\frac{1}{24}\ wl^2$ and the maximum negative moment $\frac{1}{12}\ wl^2$. For the lower portion of the wall a great deal of the stresses will be taken to the sloping bottom, but it will be on the safe side to assume the wall as continuous over three supports. When the slab is reinforced in both directions, the analysis becomes more complex. For square slabs such as this would be, if not supported in the middle, the reinforcement would be equal in all directions. For rectangular slabs the relative amount of stress on the system parallel to the long side of the slab becomes less.

In the case of the side walls in the tank under consideration, if a beam is used to strengthen the slab in the center, they become oblong panels, while they remain approximately square if not so supported. This theoretical consideration cannot be of any effect in this case, because one side of the slab, i.e., the top, is unsupported.

The slab will therefore be designed as if composed of a series of horizontal beams, loaded uniformly by water pressure on the inside and earth pressure on the outside.

The pressures will be as follows:

Water $p = wh$ $w. = 62.4$ pounds cubic feet

	pounds square feet
4 feet depth	249.6
8 feet depth	499.2
12 feet depth	748.8
16 feet depth	998.4

Earth $p = wh\frac{l + \sin\phi}{l - \sin\phi}$ $w = 100$ pounds cubic feet $\phi = 30$

	pounds
4 feet depth	133.33
8 feet depth	366.66
12 feet depth	399.99
16 feet depth	533.32

When supported in the center of the long side, the slab has a span of 11 feet, and the beams are considered as fixed at both ends and the middle, so that a maximum negative moment of $\frac{1}{12}\ pl^2$ will be developed over the ends and a maximum positive moment of $\frac{1}{24}\ pl^2$ in the center.

The reversal of stress due to earth pressure, when the tank is empty, will have to be taken care of independently by reinforcement placed on the opposite sides of the wall from that required for water pressure. While theoretical analysis would show a possible reduction in total amount of steel, due to the presence of reinforcement in both sides of the slab, it would seem unwarranted in this analysis, because of the large number of indefinite factors in the cases.

Then for water pressure at the bottom $w = 998.4$ pounds square foot, $l = 11$, $l^2 = 121$, $M = \frac{1}{12} \times 998.4 \times 121 \times 12 = 120{,}768$ inch-pounds, $fs = 15{,}000$ pounds, $fc = 600$ pounds, $n = 15$

then

$$p = 0.0075$$
$$k = 0.375$$
$$j = 0.875$$
$$M_s = 15{,}000 \times 0.0075 \times 0.875 \times 12 \times d^2$$

or $$d = \sqrt{\frac{M_s}{f_s\, pjb}} = 10.1 \text{ inches.}$$

A 12 inch wall will then be assumed, and with $p = 0.0075$, there will be required 0.909 square inches of steel per foot width. This will require $\frac{3}{4}$ inch bars spaced 8 inches.

Vertical reinforcement will be $\frac{1}{2}$ inch rods, 18 inch centers, wired and clamped to horizontal rods.

The same thickness of wall will be assumed to the top, which is on the side of safety. For earth action inwards pressure would be 533.3 pounds square feet and $M = \frac{1}{12} \times 533.3 \times 121 \times 12^2 = 64{,}500$ inch-pounds.

To find d, assuming $b = 12$ inches, $d = \sqrt{\frac{M_s}{f_s\, pjb}}$, p and j would be as before. $d = 7.38$ inches and there would be required 0.0075×7.38 inches $\times$ 12 inches or 0.675 inch per square foot width, which would require $\frac{5}{8}$ inch square rods spaced 7 inches and with proper reduction. At the 12 foot height, the moments are reduced 25 per cent, and $d = 76.5$ for water and 40.7 for earth. The corresponding values of d are 8.75 inches and 6.4 inches, while the steel required is

$$0.0075 \times 8.75 \times 12 \quad = 0.79 \text{ square inch}$$
$$0.0075 \times 12 \times 6.4 \text{ inches} = 0.58 \text{ square inch}$$

This requires $\frac{3}{4}$ inch rods spaced 9 inches and $\frac{5}{8}$ inch rods spaced 8 inches. At the 8 feet height, 0.67 square inch and 0.50 square inch are required, which requires the

$\frac{3}{4}$ inch rods to be spaced 10 inches and the
$\frac{5}{8}$ inch rods to be spaced 9 inches.

For the last 4 feet both rods will be spaced 12 inches centers. In the case of the circular tank, the stresses will be determined in the same conditions. For pressure on the inside, the entire tank will be under tension, and would be designed in that way with vertical distribution. When empty (i.e., earth pressure acting) a uniform compression will be caused in the entire ring.

In the circular tank, the tensile stress at all points in a circular ring 1 foot high will be

$$t = \frac{18 \text{ feet} \times 998.4 \text{ pounds}}{2} = 8985.6 \text{ pounds.}$$

This would require, with steel at 16,000 pounds per square inch, $\frac{8985.6}{16{,}000} = 0.56$ square inch per unit width. The thickness with $p = 0.0075$ would then be

$$\frac{0.56}{0.0075} = \frac{74.7}{12} = 6\tfrac{1}{2} \text{ inches} \qquad \frac{74.7}{12} \text{ or } 6\tfrac{1}{2} \text{ inches approximately.}$$

Assuming a 7-inch wall, the earth pressure would produce a concrete stress

$$\frac{18 \text{ feet} \times 533.3}{2} - \frac{8985.6 \text{ pounds}}{84} = 107 \text{ pounds per square foot}$$

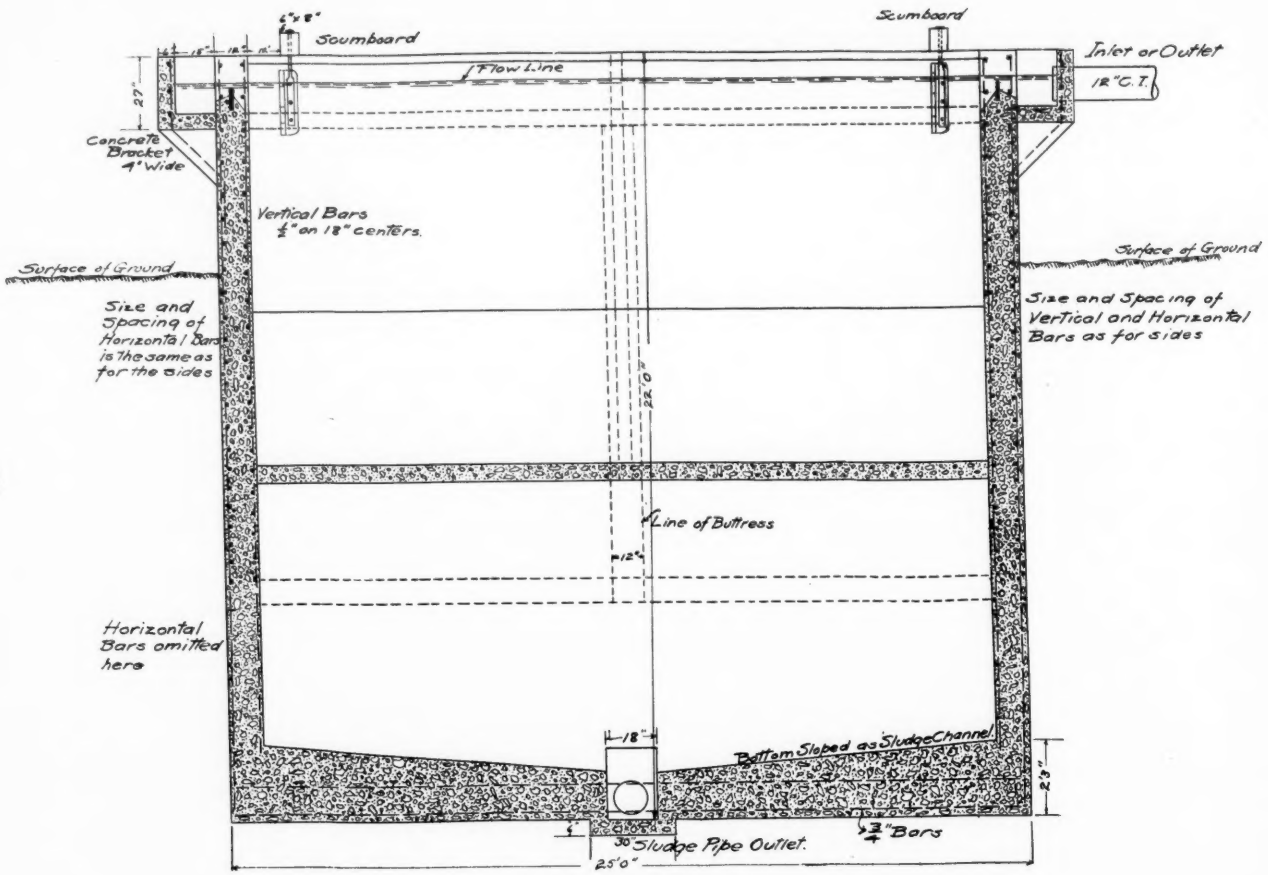
compression on the concrete.

While 7 inches would seem adequate, common practice in this type of wall is considerably heavier, so that a 12 inch wall will be used throughout.

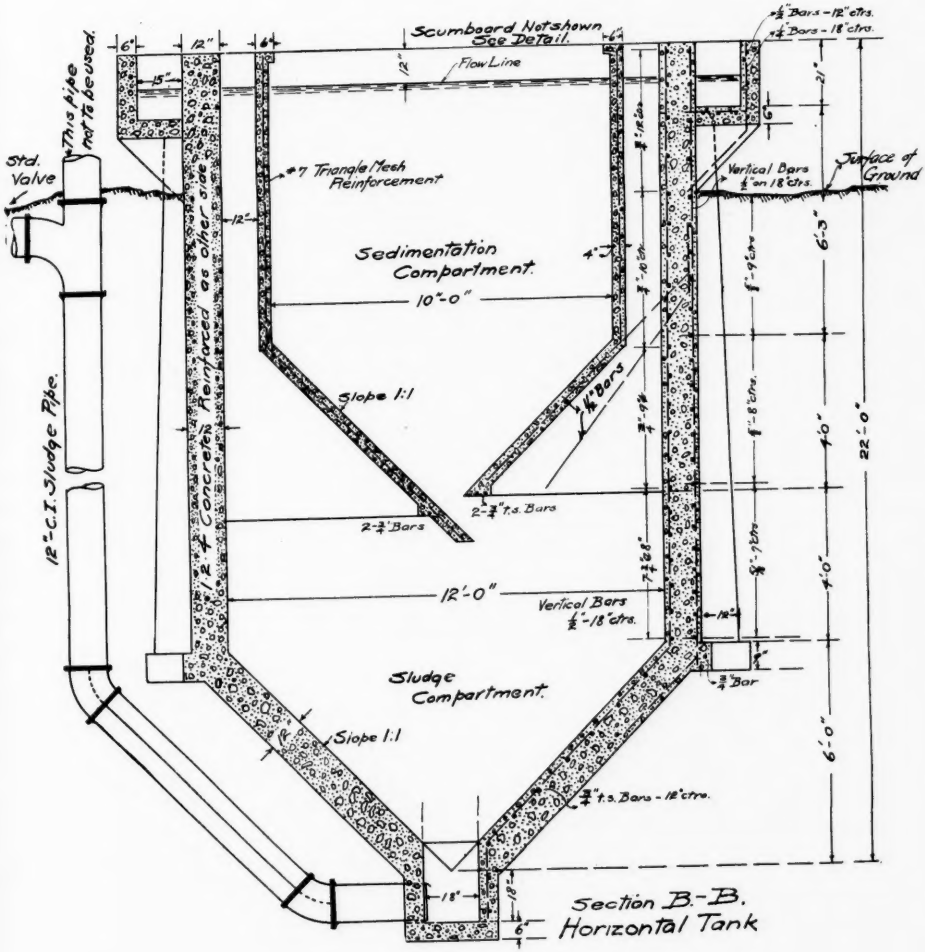
Three-quarter inch twisted bar spaced 10 inches and 12 inches will be used for horizontal reinforcement, while vertical reinforcement will be $\frac{1}{2}$ inch rods spaced 18 inches centers.

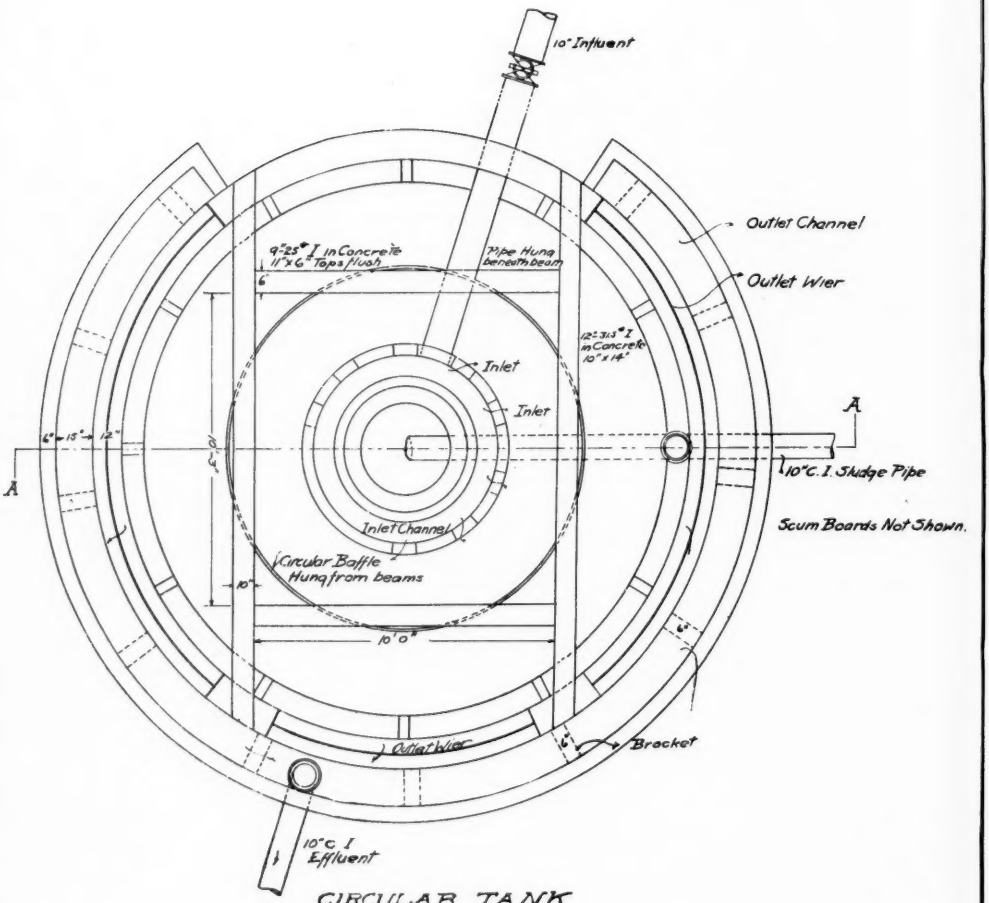
Rectangular tank—description. The rectangular tank, as designed, has a tank, 22 feet by 12 feet internal dimensions, and a depth of 22 feet to the bottom of the digestion chamber. The walls are straight and vertical throughout their height, reinforced inside and outside as calculated above for earth pressure and for water pressure. The sedimentation chamber is separated from the digestion or sludge chamber by dividing walls 4 inches thick of concrete, reinforced by triangle [M] mesh or similar metal reinforcement. The sides are supported in the middle of their length by buttresses calculated as cantilevers, while the dividing wall is supported at the ends by the end walls of the tank and in the middle by a wall extending to the level of the slot and reinforced by rods to the main wall.

The tank is so arranged that the sewage flow may be reversed in direction through the sedimentation chamber. This is accomplished by a concrete channel 15 inches wide supported on brackets and an arrangement of stop planks of 2 inch boards properly arranged. Sludge is removed from the bottom of the tank by means of a 12 inch cast iron pipe.

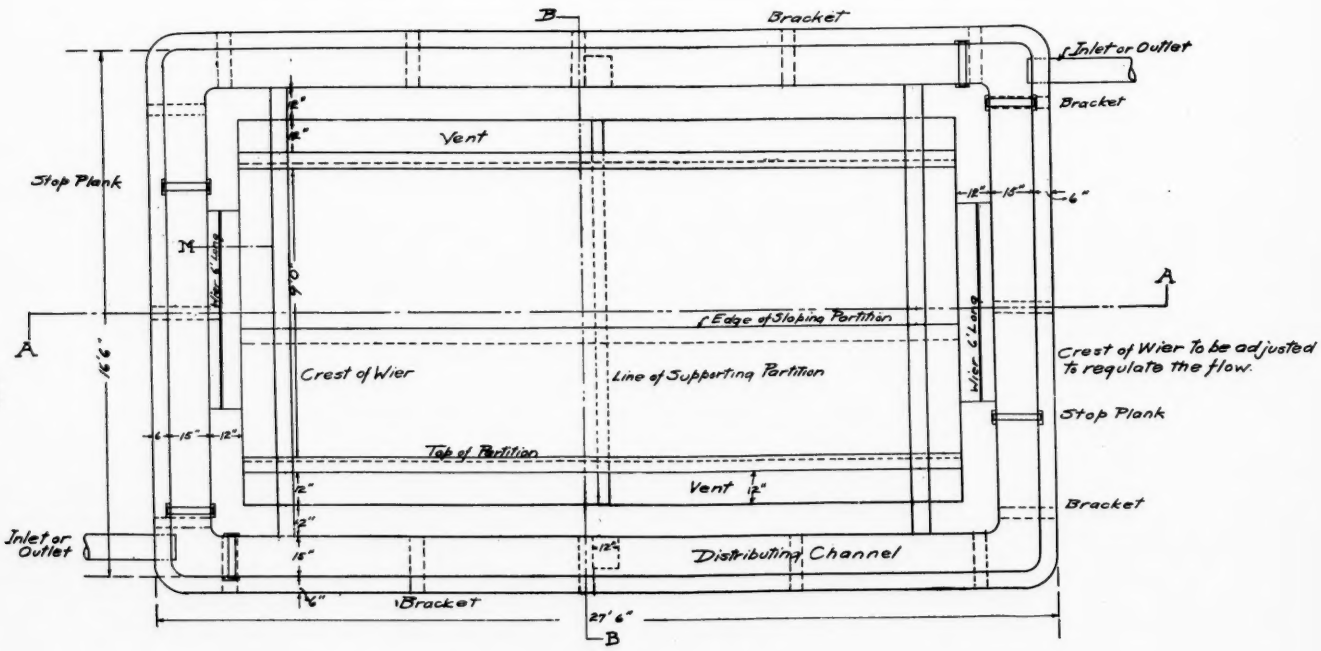


SECTION A-A
Scale: ½"=1'
Horizontal Tank


Scumboard Not shown See Detail
Flow Line
Std. Valve
This Pipe not to be used
#7 Triangle Mesh Reinforcement
12"-C.I. Sludge Pipe
12" Concrete Reinforced as other side
Sedimentation Compartment
10'-0"
Slope 1:1
2-¾" Bars
2-¾" t.s. Bars
12'-0"
Vertical Bars ½"-18" ctrs.
Sludge Compartment
Slope 1:1
¾" t.s. Bars - 12" ctrs.
¾" Bar
½" Bars - 12" ctrs.
½" Bars - 18" ctrs.
Vertical Bars ½" on 18" ctrs.
Surface of Ground
6'-3"
22'-0"
6'-0"
Section B-B.
Horizontal Tank



CIRCULAR TANK
PLAN
Scale :- $\frac{1}{2}$" = 1'



PLAN
OF
HORIZONTAL TANK
Scale:- $\frac{1}{2}$"=1'

Sewage enters the sedimentation chamber from the channel over a weir, which is of wood or steel, and can be adjusted in length to produce satisfactory velocities in the tank. Scum-boards are provided at points of inflow and outflow, which may be dispensed with if the sewage is screened previously to its admittance in the tank.

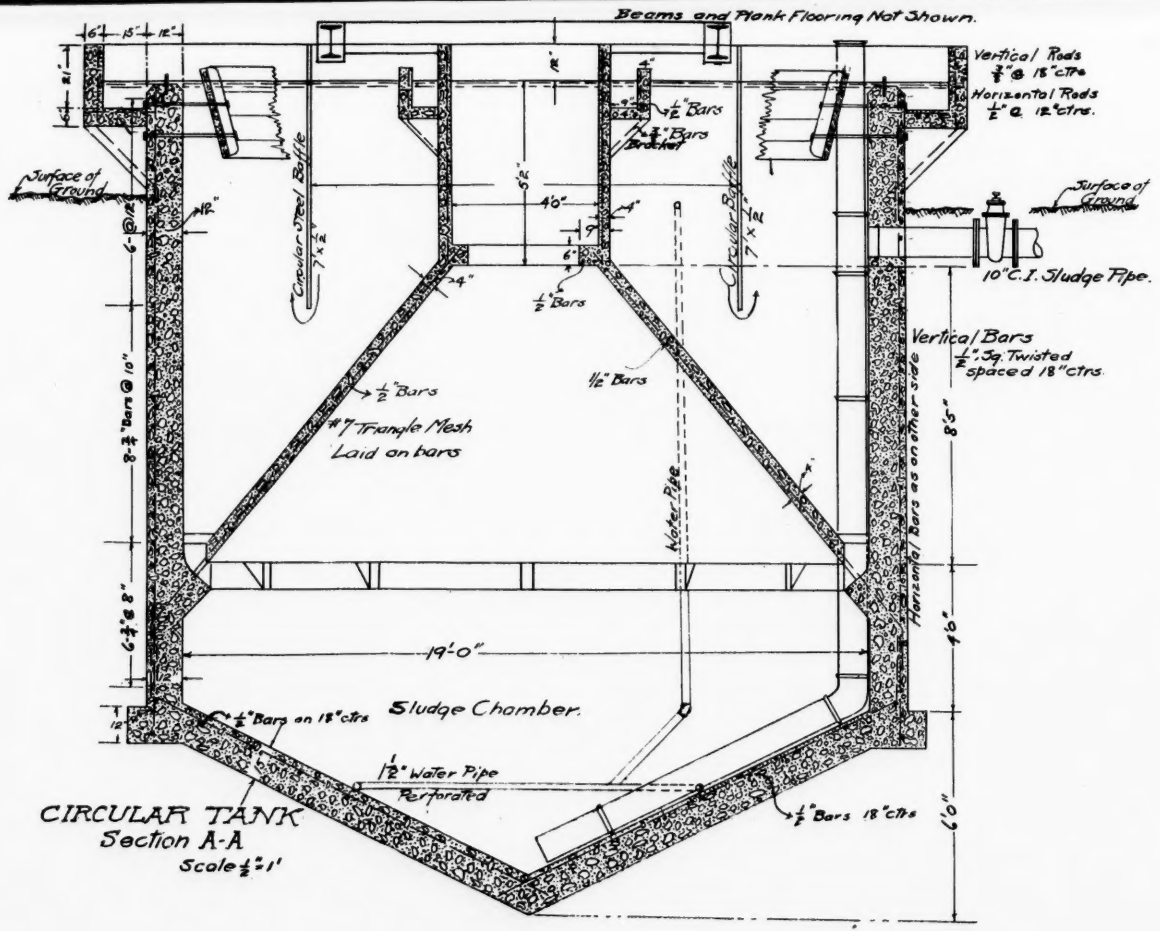
Concrete for the tank shall be in the proportion of 1 : 2 : 4, with either gravel or broken stone of graded sizes. Reinforcement steel is of best quality and must satisfy the specifications of the American Society of Civil Engineers, as found in their last report. Two lines of perforated pipe are placed in the bottom of the digestion chamber, to aid in stirring up the sludge and facilitating its discharge through the discharge pipe.

Circular tank—description. The circular tank is 19 feet in internal diameter, and has a depth below the water line of 22 feet 6 inches. The bottom is conical shaped, the concrete being 15 inches thick and reinforced by radiating bars with circular rods at 18 inch intervals. The dividing walls between the upper and lower compartments is of reinforced concrete, supported by 4 inch brackets to the main wall of the tank at regular intervals. The upper part of conical partition terminates in a circular vent, which supports the distributing channel. Inflowing sewage is conducted by a cast iron pipe to this circular trough or channel, from which it flows through openings of adjustable size into the sedimentation chamber, down under a baffle and out to the outer wall of the tank, portions of which are constructed as weirs and allow the discharge of the clarified sewage into a circular trough on the outside wall, from which it is led to the drainage or filter beds.

Sludge is removed by a 12 inch cast iron pipe lying along the bottom and up one side to an elevation far enough below the water level to furnish proper hydrostatic head.

Baffling is secured by means of a circular baffle, constructed of steel and hung from beams across the top of the tank. These beams are standard I beams encased in a concrete coating to prevent corrosion and add homogeneity to the appearance.

Reinforcement is placed in the outside of the walls and on the conical bottom, and concrete and reinforcement are subject to the same specifications as in the rectangular tank.


Beams and Plank Flooring Not Shown.
Vertical Rods
⅞" @ 15" ctrs.
Horizontal Rods
½" @ 12" ctrs.
½" Bars
Surface of Ground
Circular Steel Baffle
7 x ½"
Circular Baffle
7 x ½"
10" C.I. Sludge Pipe.
Vertical Bars
½" Sq. Twisted
spaced 18" ctrs.
½" Bars
#7 Triangle Mesh
Laid on bars
½" Bars
Water Pipe
Horizontal Bars as on other side
19'-0"
Sludge Chamber.
½" Bars on 18" ctrs
½" Water Pipe
Perforated
½" Bars 18" ctrs
CIRCULAR TANK
Section A-A
Scale ½" = 1'

Comparisons and Conclusions

The comparison of the two tanks will be made on the basis of their cost, clarification efficiency and general qualifications.

cost

In discussing the estimated cost of the tanks, two methods will suggest themselves. One way would be to assume the same unit costs for all items under both tanks and this would resolve itself in a question of comparative quantities, plus whatever extra appurtenances were to be found in either tank.

Several objections can be maintained against this method. First, there will undoubtedly be a difference in the cost of forms, in the circular tank requiring more lumber waste, more carpenter work and more difficult construction. Secondly, the bending and placing of reinforcement takes more time and labor and is more expensive to hold in place. Again, the placing of concrete may be found to be more difficult in the circular forms.

The method of estimating costs that will be followed herein is as follows:

A detailed list of every operation necessary to the construction of each tank will be made, the quantities of each and unit costs for same. The products of quantities and costs, together with whatever operations are scheduled as lump sums, will be equal to the total cost of the tanks.

It may be stated here that cost data that will effectually distinguish between circular and rectangular construction is extremely unreliable and variable. Differences in prices of materials and labor, faulty or insufficient accounting systems, location with respect to supplies and management prevent any adequate or convincing figures.

In the present estimates, only those items which would be liable of any variance will be affected by different prices.

The following items to be found in the construction of both tanks may be said to have probable differences:

Sheeting. This, if necessary for good work in concreting, might seem to be different, but if ordinary sheet piling be used or sheeting supported and braced by waling pieces, the difference in cost would be negligible, for the possible added cost of erection in the circular tank would be offset by the smaller quantity required.

Placing reinforcement in floor. The conical bottom would require much more careful placing, more cutting, and this difference will be taken care of by estimating the cost as 5 cents a pound for the rectangular tank and 6 cents for the circular.

Concreting floors. There will probably be little difference here, as there will be no forms in either tank and small difference in finishing.

Forms for walls. Owing to the extreme variability in cost of lumber, the dearth of adequate or satisfactory cost data, this item will not be considered separately but will be included in the cost of concrete in the two instances as noted below.

Reinforcement for walls. Variations in prices for this will be taken care of in the same proportion as in placing reinforcement for the floor; that is, 5 cents a pound for the rectangular walls and 6 cents a pound for circular.

Concrete for walls. After investigation of cost data covering all available sources, it seems within the limit of accuracy to assume a difference in price for the concrete in circular walls over that in the rectangular walls and to include in that difference all items involved that would be affected. The items involved are erecting forms, placing reinforcement and placing concrete. The price for the rectangular tank will be taken as $12 a cubic yard and that for the circular tank at $14 a cubic yard.

All other items common to both tanks will be assumed at the same unit costs.

QUANTITIES FOR RECTANGULAR TANK

Concrete:	*cubic yards*
Sides	28.5
Ends	16.9
Bottoms	13.2
Buttresses	0.9
Channels	6.2
Partition	9.3
	75.0

Timber:	*feet*
57 feet — 2 x 6 inch cypress plank	57
12 feet — 2 x 4 inch cypress plank	8
28 feet — 6 x 8 white oak plank	112
32 feet — 2 x 6 inch cypress plank	32

Excavation:
400 cubic yards

Piping:
22 feet—12 inch cast iron pipe
65 feet—1½ inch perforated water pipe
1—12 inch cast iron valve
2—12 inch 45 degree turns
1—12 inch 90 degree tee
2—6 feet x ½ inch x 4 inch steel plates

Bolts and nuts:
9—6 inch x ⅜ inch bolts and nuts
24—4 feet x ½ inch bolts and nuts
6—wrought iron strap bolts with nuts

REINFORCEMENT FOR RECTANGULAR TANK

Partition:
744 square feet No. 7 triangle mesh
98—¾ inch bars @ $1.91 pound, 183.5 pounds

Walls:	*pounds*
775 feet—½ inch bars @ $0.85 pound (vertical outside)	659.0
575 feet—½ inch bars @ $0.85 pound (vertical inside)	488.5
828 feet—¾ inch bars @ $1.91 pound (horizontal inside)	1582.0
529 feet—⅝ inch bars @ $1.33 pound (horizontal outside)	704.0

End walls:	*pounds*
(vertical) 16 x 20 = 320 feet — ¾ inch bars @ $1.91 pound	612.0
(horizontal) 21 x 12.5 feet = 262.5 feet — ¾ inch bars @ $1.91 pound	502.0
23 x 13.5 feet = 310.5 feet — ⅝ inch bars @ $1.33 pound	412.5

Brackets:	*pounds*
6 x 89 feet = 544 feet—½ inch bars @ $0.85 pound	462.0
60 x 5 feet = 300 feet—⅜ inch bars @ $0.478 pound	143.5

Walls supporting partition:	*pounds*
4—10 feet, ½ inch bars @ $0.85 pound,	34.0

QUANTITIES FOR CIRCULAR TANK

Concrete:	*cubic yards*
Side walls	44.20
Bottoms	11.61
Brackets for channels	4.85
Partition	3.80
Beam covering	1.00
	65.46

Reinforcement:	*pounds*
24—½ inch bars at 22 feet (vertical—wall) =	448.0
23—¾ inch bars at 70 feet (horizontal—wall) =	3085.0

5—½ inch bars at 80 feet (horizontal—brackets) =	340.0
12—½ inch bars at 20 feet (partition) =	204.0
12—⅜ inch bars at 6 feet (vertical—brackets) =	34.5
12—⅜ inch bars at 4 feet (vertical—brackets) =	23.0
5—½ inch bars at 40, 50, 60, 65, 70 feet (bottom—circular) =	242.5
6—½ inch bars at 4 feet (inlet channel) =	20.2
2—½ inch bars at 4 feet (inlet channel) =	6.8
12—½ inch bars at 12 feet (bottom radial) =	122.5
6—½ inch bars at 6 feet (bottom radial) =	30.6
Total	4567.1

Excavation:
350 cubic yards

Steel:
2—9 inch—25 pound I-beams at 10¼ feet long
2—12 inch—31.5 pound I-beams at 17½ feet long
200 square feet triangle mesh
3 Plates—6 x ½ inch—total length = 35 feet weir plates
1 Plate 37 x 7 feet x ½ inch

Pipes and fittings:
23 feet—10 inch cast iron water pipe
1—45 degree—12 inch turn
1—90 degree—12 inch turn
1—12 inch standard valve
6—ring pipe supports
60 feet—1½ inch water pipe—32 feet long perforated ⅛ inch holes spaced 4 feet

ESTIMATE OF COST FOR RECTANGULAR TANK

Excavation:	
400 cubic yards at $0.45	$180.00
Sheeting:	
100 linear feet at $1.75	175.00
Placing cast iron sludge pipe:	
22 feet—12 inch pipe at $2.00	44.00
Setting valve	5.00
Back filling and tamping sludge pipe trench	1.50
Placing reinforcement in floors:	
1000 pounds at 5 cents	50.00
Concreting floors:	
13.2 cubic yards at $12.00	158.00
Waterproofing:	
6½ squares at $3.50	22.70
Reinforcement for Walls:	
5542 pounds at 5 cents	275.00
Concrete for walls:	
46.3 cubic yards at $12.00	550.00

Reinforcement for partition:	
744 square feet No. 7 triangle mesh at $2.50 a square 217.5 pounds bars at 7 cents	18.00
Concrete in partition:	
9.3 cubic yards at $20.00	185.00
Steel weir plates	3.40
Water pipe placed:	
65 feet—1½ inch pipe perforated and fitted with connections. Lump sum	50.00
Reinforcement for brackets and channels:	
605.5 pounds at 7 cents	42.40
Concrete for brackets and channels:	
6.2 cubic yards at $16.00	100.00
Materials for scumboards and supports	15.00
Making and hanging same	10.00
Making stop planks	20.00
Backfilling and embankments	25.00
Placing influent pipe and connections	15.00
Total estimated cost	$2126.40

ESTIMATE OF COST FOR CIRCULAR TANK

Excavation:	
350 cubic yards at $0.45	$157.50
Sheeting:	
80 linear feet at $1.75	140.00
Reinforcement in floors:	
400 pounds at 6 cents	25.00
Concreting floors:	
11.6 cubic yards at $10.00	116.00
Waterproofing:	
3.7 squares at $3.50	15.00
Reinforcement for walls:	
3533 pounds at 6 cents	215.00
Concrete for walls:	
44.2 cubic yards at $14.00	620.00
Placing sludge pipe:	
23 feet—12 inch at $1.50	35.00
Placing sludge pipe valve	40.00
Specials	10.50
Reinforcement for partition:	
300 square feet triangle mesh at $3.00	10.00
231 pounds at 7 cents	18.00
Concrete for partition:	
3.8 cubic yards at $20.00	75.00
Circular steel baffle:	
5400 pounds at 4 cents	210.00

Placing steel beams:	
1600 pounds at 4 cents	65.00
Water pipe placed:	
60 feet—1½ inch pipe—perforated and fitted	50.00
Reinforcement for brackets and channels:	
400 pounds at 7 cents	28.00
Concrete in brackets:	
4.85 cubic yards at $16.00	75.00
Concrete in top beams	20.00
Weir plates	10.00
Placing influent pipe and connections	15.00
Total estimated cost	$1950.00

In the estimate of cost, certain variations in cost items, not hitherto mentioned, are to be found.

The sludge pipe can be placed in the inside of the finished tank more cheaply than in the earth outside, hence the prices of $1.50 and $2 respectively.

Reinforcement in floors is given at 5 and 6 cents a pound, as previously noted.

Concreting floors is given at $10 in both tanks.

Reinforcement for walls is given at 5 and 6 cents as noted, and for reasons already given.

Concrete for walls is given at $12 and $14.

Triangle mesh in place is assumed at $2.50 and $3 and the lump sums are not those obtained by strict multiplication.

Concrete in the partitions is given at $20 and in the outside brackets at $16. While these are only estimates, it would seem that they are close enough to the proper value.

A cheaper type of baffle and top construction for the circular tank would materially increase the financial advantage of the circular tank. The resulting estimates from the above considerations do not allow much advantage to either side, and peculiar conditions might even throw this advantage entirely on the other side.

However, it would seem that while the units cost has been figured as greater for the circular tank, the often stated advantage of that latter type over the former may be seen to be based on a small margin of difference.

CLARIFICATION EFFICIENCY

As regards clarification efficiency, certainly the advantage will lie in the circular tank. While the advantage of the deep baffle may not be great, certainly the period of low velocity will be of value in securing efficient sedimentation. The uniform flow in radial lines will remove the necessity for ever reversing flow and will stabilize the flow in such manner as to permit the most normal conditions of settling.

In consideration of the many probable items of difference and chance involved in either estimate, when applied to a single installation, it would be the writer's conclusion and thesis that the advantages of the circular radial-flow type of Imhoff tank over the type known as rectangular-linear flow must lie mainly upon its advantages as to clarification efficiency. And here too, enough questions will arise to make the problem one that can be best solved for each location or installation.

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GEOGRAPHIC FACTORS IN THE ESTABLISHING OF THE OHIO-MICHIGAN BOUNDARY LINE[1]

CONSTANCE G. EIRICH

Herder tells us that history is geography set into motion; Miss Semple says: "Today a fact of geography becomes tomorrow a factor of history." Several facts of geography are fundamental in the dispute between Ohio and Michigan over the boundary question. In origin, this long and bitter quarrel resembled the state and colonial contentions over boundaries, all of which arose from either ignorance of local geography, or an unpardonable disregard of vested rights. Michigan claimed her boundary as a vested right from the ordinance of 1787;[2] whereas Ohio urged that the ordinance based its determination on erroneous geographical facts; hence the boundaries as laid down in it should not be strictly binding.

The geographic factors involved in the question are: (1) the true location of the Southern end of Lake Michigan; (2) the physiography, coast line and harbors of the western part of the Erie basin; (3) the prospective canals of Ohio; (4) population, i.e., relative size of the two groups concerned.

SOUTHERN END OF LAKE MICHIGAN

In the ordinance of 1787, Congress reserved the right to form one or two states in that part of the North West Territory which lay north of an east-west line drawn through the southern bend or extreme of Lake Michigan. This line would form the southern boundary between the states to be created later. The trouble arose from the fact that due care was not exercised in determining the line. Maps of the Western country extant at the time of the ordinance was adopted show the south end of Lake Michigan to be so far north of its true position that the northern boundary of the

[1] This paper was prepared in connection with a course in geography at the University of Michigan, under the direction of Prof. Frank Carney. Reprinted from *Journal of Geography*, vol. xii, pp. 5–8, September, 1913.

[2] Tuttle, Charles R., *General History of Michigan*, 1873, p. 450.

territory of Ohio was laid down at nearly the 42nd parallel, being indicated on the map by a pencil line drawn from the southern bend of the lake to the Canadian line, intersecting Lake Erie between the River Raisin and the town of Detroit. No further thought was given this indefinite boundary until Ohio moved to become a state. Ohio's constitutional convention, which convened at Chillicothe in 1802, was proceeding on the assumption that the old maps were correct, and the line as defined in the ordinance would terminate at some point north of Maumee Bay. While the subject was under discussion, a man, formerly a hunter in the Lake Michigan country, mentioned the fact that the lake extended much farther south than was generally supposed. This possibility immediately alarmed the members of the convention, who, in order to provide against the contingency that the line mentioned in the ordinance, might be further south than was commonly supposed, inserted in their constitution the famous "proviso" to the effect, that if the southern bend of Lake Michigan should extend so far south that a line drawn due east from it should not intercept Lake Erie, or if it should intersect the lake east of the mouth of the Maumee River, then with the assent of Congress, the northern boundary should be established by, and extend to, a line running from the southern end of Lake Michigan to the most northerly extreme of Maumee Bay.[3] Ohio's constitution was accepted by Congress, though no special mention was given to the "proviso." Owing to the fact, however, that the constitution was accepted by Congress, many Ohio people took it for granted that Congress had recognized the "proviso," and that the line was thus legally fixed. The boundary dispute therefore had its genesis in an incorrect map.

Area in Dispute

Population in this area was so sparse that the boundary line question was dormant till the expanding industries of the more thickly settled parts of Ohio demanded transportation outlets, and the state began to discuss canals. Lake ports, and their hinterlands at once became regions worth serious consideration. Michigan held to the line as literally laid down in the ordinance, since it gave her the harbor of Maumee with a strip of land 5

[3] Cooley, Thomas M., *Michigan*, 1905, pp. 216–217.

miles wide on the west and 8 miles wide on the east. Naturally Ohio urged the boundary of her "proviso" which placed these advantages in her domain. The limits which Michigan proposed would have made her a larger state than Ohio and one of the largest in the Union at that time; Ohio would then be one of the smallest of the western states. Furthermore, Michigan would have a longer coast line than any other state of its size; Ohio, being on one of the smallest of the Great Lakes, would have very little coast line. Hence it seemed equitable to give Ohio all the coast line that was possible even at the expense of Michigan. If Michigan did lose Maumee Bay she still had a good harbor on Lake Erie. At that time, Ohio was considered the key to the west because of her location between the new and the old country, and her accessibility to old centers of settlement, hence the commercial interests of Ohio, as well as of the country at large, demanded that Ohio should have as many lake ports as possible.

Prospective Canals

Associated with the Maumee harbor is perhaps the most important factor in the boundary dispute—the influence of the canals. The Erie Canal, completed in 1825, stimulated the western states to open up their interiors by canals, that they might profit through this waterway to the east. The stimulus was first felt by Ohio because of its nearness to the western terminus of the Erie Canal. The long lake frontier on the north, the narrow width between Lake Erie and the navigable Ohio on the south and east, and the interior rivers, suggested the feasibility and advantages of an extensive system of artificial waterways. At this time, too, steamboats were operating on the lakes and rivers, greatly enhancing the value of Maumee Bay as well as developing the full usefullness of the interior water ways, both as avenues of immigration and means of trade.

The next influence bearing on the boundary question was the Miami-Erie Canal which was to connect the Ohio River at Cincinnati with Lake Erie. This canal was contemplated about 1825 and begun in 1830 though not completed until 1845, almost eight years after the boundary was fixed, that is, in 1837, the year Michigan was admitted as a state. It was the anticipated advantages of the canal which affected the boundary question. The

Wabash-Erie Canal was surveyed in 1836 and completed about 1845; but the agitation which resulted in this canal was an important factor in the boundary dispute. The canal propaganda was supported by Ohio capitalists and by those interested in Ohio, but living in the east, a group of whom had undertaken to build a city at Toledo, and others had interests in other towns of the disputed territory. These men were actively interested in Ohio's contention over the boundary; they foresaw that canals would be a means of opening up a large central area of farms which formed an isolated district practically cut off from the Ohio River and the lake, and would thereby increase the growth and prosperity of the state.

The Miami-Erie Canal was considered a good transportation route for manufacturers from the eastern cities to the great river valley at, and below Cincinnati. The Wabash-Erie Canal was expected to control Indiana trade. Toledo, aided by these canals and its position on the lake, was predicted to be one of the greatest gathering points of agricultural productions in the country; and was considered equally favorable for the distribution, over the lakes, of southern products, sugar and tobacco. At that time canals were the most important means of transportation. Their construction required large expenditures, and too great risk as to profits for individuals or companies to undertake, hence the canals were to be owned by the state. Ohio, having a relatively dense population, and considerable wealth, was able to undertake constructing canals; her accessibility to the older centers of settlement was a factor in the prevalent optimism. Ohio capitalists recognized the natural advantages of Toledo as the northern terminus of a canal; other termini were considered, but Toledo was found to be the only practicable one from an engineering point of view. The industrial purposes of a canal in western Ohio would be but partly fulfilled if some other harbor had to be used. Ohioans therefore insisted upon the "proviso" of their constitution.

Thus when Michigan began to make known her claims to the boundary as specified in the ordinance, canal building came to a sudden halt. Toledo was the physiographic terminus; the thought of Ohio constructing so expensive a channel of trade and then turning its traffic into a Michigan port was not to be entertained. Michigan was anxious to avail herself of whatever ad-

vantage she might receive from her neighbors' necessity. The boundary question did not assume its really great importance until the northern terminus of the Miami-Erie Canal came up for final decision. The inhabitants of the disputed district had acquiesced in being ruled by the Michigan Territory; however, the boundary line discussion soon led them to take the side of Ohio; the population immediately concerned in the disputed area did not support Michigan.

Population as a Factor

Northern Ohio did not have a large population in 1830; in the Ohio part of the Maumee drainage basin there were about 11,000. The contiguous part of Michigan contained about 15,500. So far as the ratio of local population is concerned the advantage was with Michigan. In 1840 the population of these same regions of Ohio and Michigan was 56,680 and 75,555 respectively. From these statistics alone we would expect Michigan to have had the greatest influence, though we know such was not the case.

The question in dispute was of interest to the entire population of each political division; consequently in this particular the strength of the two political divisions was measured by their relative populations. In 1830 the population of Ohio was 937,903, of Michigan, 31,639; in 1840 Ohio numbered 1,519,467, while Michigan had only 212,267. Capitalists of Ohio, as well as eastern capitalists who were interested in Ohio, had faith in numbers, and accordingly exerted all the political influence possible. Michigan did not have a corresponding population-momentum, a vital geographic influence, though only a corollary of more basal geographic factors. A Michigan delegate to Congress, Mr. A. E. Wing, declared[4] that a Cincinnati company, interested in the canal, and bodies of eastern capitalists, sent lobbies to Washington to induce Congress to extend the domain of Ohio to the northern boundary. Furthermore, Ohio's population was an influential political body whose good will was essential to the President in the coming election, though this fact as a basis for the President's action in the case may have operated only subconsciously.

[4] Soule, A. M., *Southern and Western Boundary of Michigan.* Mich. Pol. Sc. Ass., vol. ii, no. 2, May, 1896, p. 51.

Conclusion

These four factors: the position of the southern end of Lake Michigan; the physiography of the Maumee basin and its harbors; the prospective canals; and the momentum of the populations involved, were very important in establishing the boundary line. There were years of Congressional disputes; and politics in its good and bad phases became a feature, but these were only manifestations of the fundamental geographic influences.